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Editorial

Rust reminds us of old and neglected machinery and infrastructure, something that most engineers tend to avoid. However, for a certain type of materials engineer, rusting is a complex process and understanding it worthy of intellectual pursuit. With all its shades of colour, rust also looks strangely beautiful when examined closely. It depends on one's perspective.

In the same way, engineering education in the Global South is faced with systemic challenges and resource constraints, and something the conventional engineering academic would avoid investigating in any detail. But for the engineering education researcher, the complex space where technical knowledge meets human learning is worthy of intellectual pursuit. It is because we have been awakened to this fresh perspective that we have chosen a close-up image of a 'rust landscape' for the front cover of the Southern Journal of Engineering Education (SJEE).

The SJEE was launched in July 2021 with a successful online symposium. Ironically, without the Covid-19 pandemic, it is doubtful that the symposium would have been the success it was. The online format – which had become familiar to all by that time – allowed representation from 17 countries, including Uganda, India, Sweden and Brazil; the four keynote speakers were from four different continents; and partnering organisations in engineering education research from across the globe provided messages of support.

Most of the articles in this inaugural issue are linked to this symposium in some way. The first is entitled Evaluating and publishing curriculum development activities, and is a 'point of departure' contribution since it is derived from John Mitchell's very successful keynote at the SJEE symposium. John Mitchell has contributed – and is contributing – enormously to engineering education in Africa and his piece highlights some of the potential pitfalls in the design of curriculum development evaluations, especially when they are intended for publication. For engineering education colleagues who are negotiating the transition from technical research, this piece has real practical value.

The second article by Christine Winberg is also derived from a SJEE symposium keynote contribution but is a peer-reviewed piece that reports on a larger project on pedagogies in STEM (Science, Technology, Engineering and Mathematics). Using the theoretical framework of Activity Theory, Winberg analyses teaching portfolios of engineering lecturers applying for tenure, promotion, and awards at four different universities in South Africa. A fascinating

insight from her research is that the high-stakes nature of the teaching portfolios 'created tensions between an engineering and a teaching identity and led applicants to conceal their teaching practice rather than describing and reflecting on their practice' (p. 34).

This leads into the third article by Ashish Agrawal, Hilton Heydenrych and Genevieve Harding. It grapples with the concept of decolonisation, a philosophical idea drawn from the social sciences. Decolonisation came to prominence in South Africa following the 2015/16 student protests and there is growing interest in the notion of decolonisation in engineering education internationally. However, relatively little has been written about the practical implementation of decolonisation. The work of Agrawal and colleagues address this gap '…by providing an example of decolonising an engineering project taught to second-year students pursuing chemical engineering' (pp. 47–48).

It is fitting that the final article of this inaugural issue is co-authored by Jenni Case, a pioneer of engineering education research in South Africa who is now at Virginia Tech in the United States. Jenni continues to play an important role in engineering education in South Africa and the Global South. She also presented a keynote at the SJEE Symposium and has teamed up with STEM education scholar Margaret Blackie for a thought-provoking article. They turn to the philosophy of critical realism to explore the 'inconvenient truth' of education: the 'troubling finding that family background was a greater causal determinant of school outcomes than anything that happened in the school' (p. 65). In doing so, they open an important conversation about the causal mechanisms by which engineering education research contributes to change in broader society.

As these articles show, engineering education research in the Global South is an exciting intellectual space. The SJEE provides a scholarly forum to document the exciting journey that is before us. As part of our mission, we are following a 'diamond open access' model which means no fees for either reader or author. In this spirit of openness, we invite you to contribute to, support and share this journal with all interested colleagues and organisations. We have much to learn.

Lastly, thanks must go to the members of our international Advisory Board, the hard-working Editorial Team, and the South African Society of Engineering Education (SASEE). Without your support, we would not have reached this historic milestone.

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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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Reconceptualising teaching portfolios for professional development in engineering education

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A teaching portfolio is a collection of texts and materials that are intended to represent teaching practice. Many institutions require candidates applying for tenure, ad hominem promotion, or teaching excellence awards to submit a teaching portfolio as part of their application. Building a teaching portfolio engages candidates in reflection on their practice and has been shown to enhance teaching practice. However, less is known about how the socio-cultural contexts of different disciplines and fields shape the representation of candidates' teaching practice. To address this gap with regard to engineering education, the teaching portfolios of engineering lecturers applying for tenure, promotion, and awards at four different universities were studied, guided by the research question: How does the social context of a teaching portfolio impact the representation of teaching practice? The study found that the social context strongly influenced representations of practice. In the portfolios submitted for tenure or promotion, candidates obscured their teaching practice and instead foregrounded departmental goals or other official documents. In contrast, the award applicants provided detailed, reflective descriptions of their practice. These findings have implications for how engineering educators could be holistically supported towards enhancing their teaching practice, and its representation, in developing portfolios for tenure, promotion or awards.

Keywords: teaching portfolios, tenure; promotion, teaching awards, Activity theory

Introduction

Many South African and international universities require academic staff to submit teaching portfolios when applying for tenure, promotion or teaching excellence awards. In the South African context, most permanent academic appointments are subject to a one-year probation period, after which the incumbent is granted tenure, that is, their permanent appointment is confirmed. Many universities require the submission of a teaching portfolio towards the end of the probation period as a condition of tenure. Teaching portfolios are thus important artefacts that have come to symbolise transitions in an academic career, as well transformations in

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teaching practice. Teaching portfolios traditionally provide evidence of an educator's growth, competence, or attainment of excellence. Despite the growing use of teaching portfolios in higher education, little attention has been paid to understanding their genre within different disciplines and fields. The focus of this paper is a reconceptualisation of teaching portfolios, arguing their roles as both regulating and enhancing teaching practice in engineering education.

Data for the study was obtained from engineering educators' teaching portfolios submitted for tenure, promotion, or teaching awards. The research design draws on the research tradition around technologically-mediated communication in workplace settings (e.g., Kaptelinin & Nardi, 2006). A modelling methodology for representing knowledge work (Zachry et al., 2008) was adapted for the analysis of portfolio data. This approach understands portfolio-building as connecting chains of coordinated communication events to form a 'genre ecology' (Spinuzzi, 2002). These communication chains become the primary unit of analysis as they are representations of teaching tasks, decision points, actors, documents, or combinations of these. While much is known about the role of reflective practice in professional development towards enhancing teaching, less is known about the teaching portfolio as an artefact in a professional educational system. The study provides a framework towards reconceptualising teaching portfolios in engineering educators' career trajectories.

An additional focus of this paper is teaching portfolios developed by novice and experienced engineering educators across four universities, with a view to clarifying differences in representations of teaching practice in the teaching portfolios that are submitted at different stages in an academic career. The research question guiding this research study is: how does the social context of a teaching portfolio impact the representation of teaching practice? The assessment of a tenure or promotion teaching portfolio submission is likely to be undertaken by a departmental or faculty review committee, to which a teaching and learning expert might be invited, while the assessment of an teaching award portfolio is likely to be led by a teaching expert. The four universities are based in the Western Cape, South Africa. Three have engineering faculties and, although one has no engineering faculty, it does have engineering-related programmes and employs engineers as educators. The fields of engineering are dissimilar to the discipline of education, and stages in the growth of educational competence or the development of an educational identity are more easily identified in such disciplines (Michelsen et al., 2017).

A brief overview on the literature on teaching portfolios

Traditionally, a teaching portfolio is defined as 'a collection of materials that documents teaching performance [and] brings together in one place information about a professor's most significant teaching strengths and accomplishments' (Seldin, 2000, p. 36). Teaching portfolios were introduced into higher education in the 1990s, following a renewed interest in the role of teaching brought about by Boyer's (1990) concept of the scholarship of teaching and Schön's (1992) foregrounding of reflective practice in professional education. Seldin, echoing Boyer, claims that 'the portfolio is to teaching what lists of publications, grants, and honors are to research scholarship' (2000, p. 37). Schönwetter et al. claim that teaching portfolios turn university lecturers into 'reflective practitioners' (2002, p. 86). Teaching portfolios in higher education have a historical context. Their usage is linked to increases in student numbers, growth in student diversity, and the realisation by university managers that good teaching matters.

Early approaches to teaching portfolios recommended that practitioners should tell their 'stories', while acknowledging the complexity of most academics' stories. Over time, the teaching portfolio started to take shape as a genre, comprising a 'teaching philosophy statement', a description of the teaching context, descriptions of practice, and reflections on practice, usually supported by an appendices of evidence (Pelger & Larsson, 2018). From the outset, researchers pointed out the complexity of the genre; it was personal, but also expressed disciplinary and departmental cultures and concerns, and addressed various audiences: 'Each teaching philosophy statement reflects not only personal beliefs about teaching and learning, but also disciplinary cultures, institutional structures and cultures, and stakeholder expectations' (Schönwetter et al. 2002, p. 83).

A teaching portfolio is personal because it reveals the philosophy, accomplishments, reflections, plans and 'inevitably the personality of its author' (Graves & Epstein, 2011). The genre of a teaching portfolio is difficult to pin down because it intermingles 'cognitive, motivational, personal, and impersonal processes' in an attempt to describe the complexities of higher education teaching (Forsyth, 2016).

While the original intention of teaching portfolios was to encourage academics to share and reflect on their teaching, thereby enhancing their practice (Seldin, 2000; Schönwetter et al. 2002), teaching portfolios were soon used by managers as a way of holding academics

accountable for the quality of their teaching. Teaching portfolios thus became a way of providing managers 'with useful information in promotion/tenure decisions' (Seldin, 2000, p. 37). Unsurprisingly, teaching portfolios have not met with unanimous approval in higher education. Nevertheless, many universities have adopted the practice of requiring teaching portfolios for tenure or promotion and for teaching excellence awards. The discovery of teaching portfolios by managers tended to reshape the original narrative genre towards a form that took a more systematic approach to the measurement of teaching achievements (Kim & Kim, 2018), based on more explicit definitions of 'pedagogical competence' (Olsson & Roxå, 2013). The assessment of portfolios, and issues around credentialing, accreditation, standards of validity, reliability, fairness, and the absence of bias thus became central concerns (Kim & Yazdian, 2014). When portfolios are submitted for purposes of tenure or promotion, it 'reminds professors to monitor, measure, and even manipulate those processes' that are likely to ensure a successful outcome (Forsyth, 2016, p. 273). Portfolios can thus be used not only to enhance teaching practice, but to craft a particular teaching persona (e.g., Graves & Epstein, 2011).

Not all teaching portfolios are the same (Babin et al., 2002). Although the rationale for teaching portfolios is to encourage reflective practice (Seldin et al., 2010), differing views on their purposes have led to their adoption for different reasons. For example, teaching portfolios have been used to assess a candidate's readiness for tenure, and teaching portfolios are also a means for engaging in the scholarship of teaching and learning. These different uses of portfolios are based on paradigms that are philosophically incompatible, and thus contradictions are likely to arise in how teaching practice is represented (Leggett & Bunker, 2006).

Portfolios have been researched from a variety of perspectives. In the case of professional education, researchers have been interested in teaching portfolios as means of linking theory and practice in the education of future professionals (Boud & Brew, 2013), and resolving the tensions between professional and teaching identities (Graves & Epstein, 2011). Zhou et al. (2017) found that teaching portfolios were an effective means of enhancing new academics' teaching towards their becoming reflective practitioners. Kaasilia et al. similarly found that a reflexive approach to teaching portfolios did not cause fractured identities, but facilitated 'the development of more holistic, relational identities' amongst educators in professional fields (2021, p. 584). The literature on the assessment of professional practice (e.g., Boud & Brew, 2013) points to the importance of formative feedback for professional growth. Teaching

portfolios can provide contexts for peer review, coaching and mentoring in which teachers support their own and others' practice through portfolio building. For example, Harvard University's Best Foot Forward programme uses video-based teaching portfolios to improve classroom practice through peer review (Quinn et al., 2015).

Up until the 1990s portfolios were mainly paper-based. However, with the development of information and communication technologies, a transition towards the use of electronic portfolios (e-portfolios) that incorporate a wide variety of media occurred. While definitions of e-portfolios vary, a much-cited definition is: '…a digitized collection of artefacts, including demonstrations, resources, and accomplishments that represent an individual, group, community, organization or institution. This collection can be comprised of text-based, graphic, or multimedia elements archived on a web site or other electronic media' (Lorenzo & Ittelson, 2005, p. 3.

It has been noted that the transition to e-portfolios enables meaningful technology integration in educational development (Fong et al., 2014). The digitised nature of e-portfolios means they are more easily modified and can be regularly updated. E-portfolios are also more sharable, on institutional or personal websites, or on social media. While portfolio authoring tools have changed over the years from paper to electronic or web-based formats, they remain complex and difficult texts in terms of their social contexts and the development of an appropriate authorial voice (Torras & Mayordomo, 2011). E-portfolios need to have multiple affordances: the needs of presentation (e.g., a website affordance), as well as the process aspects of portfolio-building, such as artefact storage, sharing and collaborating, journaling, blogging, and so on: '[An e-portfolio] is the powerful intersection of multiple modes of performance that establishes the e-portfolio medium as an elastic, ultra-accessible theatrical arena in which academics may create, rehearse, and present themselves' (Ramirez, 2011, p. 1). The e-portfolio literature highlights the tensions between structured (and sometimes overly rigid) templates and more flexible constructions that allow greater creativity and innovation.

Seldin argues that a teaching portfolio is 'flexible enough to be used for tenure and promotion decisions or to provide the stimulus and structure for self-reflection about teaching areas in need of improvement' (Seldin, 2000, p. 36). The issue that this study addresses is whether the genre of the teaching portfolio is flexible enough to accommodate the socio-cultural contexts of engineering education.

Theoretical framework

In order to explore the wider socio-cultural context in the development of teaching portfolios, the study drew on the resources of Activity Theory (Engeström, 1987; 1999). Activity Theory understands that human activity is always undertaken by subjects, mediated by tools, and embedded within a social context. The interactions between subject, object, tools, and social context is known as the 'activity system' (Figure 1).

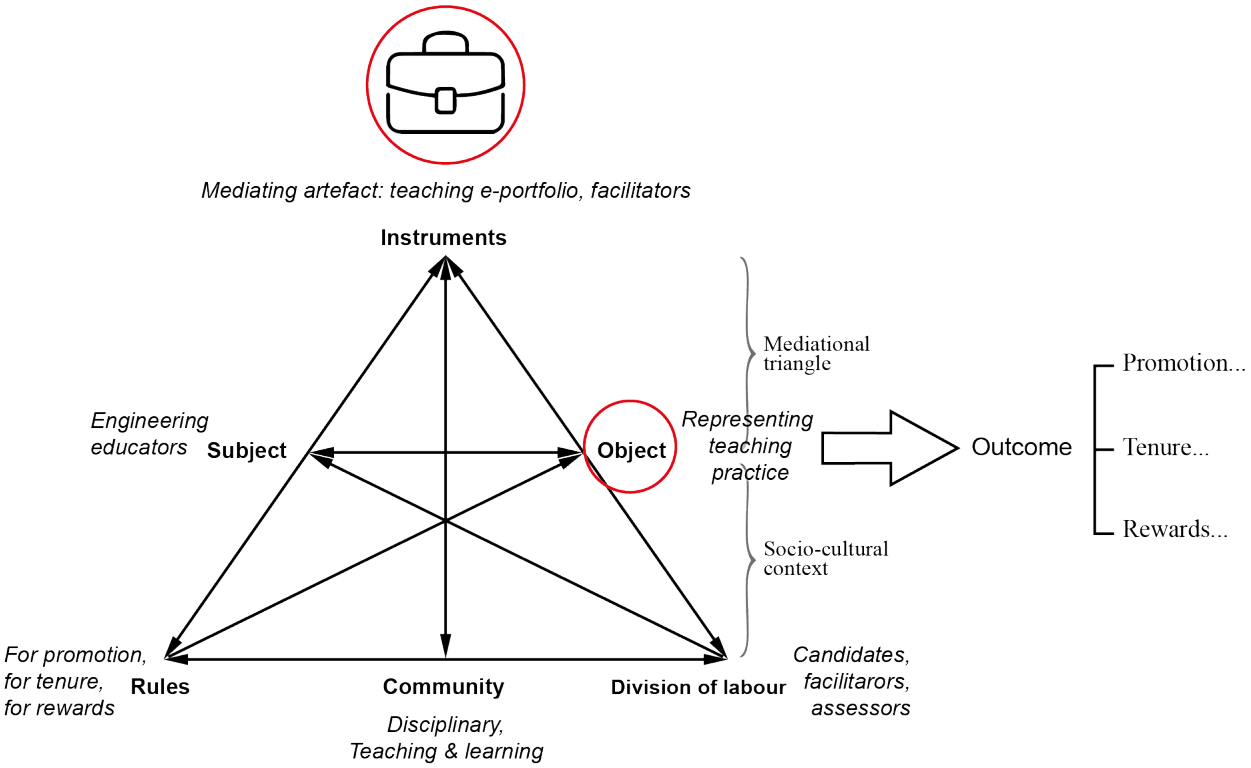

Figure 1: *The activity system of demonstrating teaching practice*

Source: Adapted from Engeström (1999)

The elements of the activity system comprise: the subjects – in this case engineering educators involved in the activity of explaining their teaching practice; mediating artefacts and persons – in this case the teaching e-portfolio and the academic development facilitators; and the object, goal or driving force of the activity – in this case describing and reflecting on and representing teaching practice. These first three elements of the activity system (the 'mediational triangle') are embedded in a socio-cultural context that includes: the rules, conventions and guidelines (of which there are many to take into consideration when applying for tenure, promotion or an award); the community, or general social context in which the teaching portfolios are developed – such as an engineering department or faculty; and the division of labour – for example, the facilitators for portfolio building are likely to be teaching

experts, while hierarchical decision-making structures for tenure or promotion are likely to be faculty-based. (Teaching experts are more likely to make decisions around teaching awards). Finally, the activity system produces an outcome of the activity, hopefully in this case, a tenure, promotion, or teaching award.

To understand how competence or excellence is demonstrated in a teaching portfolio, the whole activity system has to be studied. The first principle of activity is that the object, in this case the representation of teaching practice, will drive the activity (Engeström, 1999). The focus of this study is the mediating artefact – the teaching e-portfolio – that becomes a proxy for the candidate's practice. The mediating artefact develops as candidates engage with facilitators to find ways of representing, reflecting on and theorising their practice. A number of texts are produced and each text connects to the previous text in a sequential chain, forming a 'genre ecology' (Spinuzzi, 2002). These texts could be personal, academic, or institutional – or a mixture of all three. Texts will generally draw on what Schryer and Spoel call 'regulated' and 'regularized' resources, which are distinguished as follows: 'Regulated resources refer to knowledge, skills, and language behaviors that are recognized and required by a field or profession. Regularized resources, on the other hand, refer to strategies that emerge from practice situations and are more tacit' (2005, p. 250).

An example of a 'regulated' resource might be a faculty policy document, while an example of a 'regularized' resource could be a lecturer's teaching philosophy statement. In explaining genre ecology, Spinuzzi similarly distinguishes between: '(a) genres that are more formally or authoritatively constrained by the activity and (b) genres that represent more grounded, less authoritative, and frequently more individual or local solutions' (2012, p. 487).

The degree of authorial discretion and the emergence of an 'authentic voice' is contingent upon 'beliefs, logics, traditions, and ideologies' (p. 487). Spinuzzi's use of the term 'authentic voice' is a metaphor for the expression of identity within a genre. There is considerable difference across engineering identities as these exist at 'the intersectionality of multiple identities including race, gender, sexual orientation, and affinity towards engineering' (Patrick & Borrego, 2016). Different genres can enable or constrain different expressions of identity or 'voice'. Pelger and Larsson (2018) argue the case for teaching portfolios as enabling genres for the development of a teacher identity (p. 182), while Graves and Epstein consider the genre of a teaching portfolio to be 'multivocal' (p. 344). Teaching portfolios can express both engineer and educator voices and identities through the inclusion of both 'regulated' structures and

'regularized improvisations' (Schryer et al. 2007, p, 26). Schryer et al. argue that '[g]enres are constellations of regulated and regularized improvisational strategies triggered by the interaction between individual socialization, or habitus, and an organization or field' (2007, p. 31). While regulated genres explicitly impose an institutional (or other officially sanctioned) orientation, regularized genres introduce a different orientation dependent on the 'activities from which they are drawn' (p. 31).

Schryer et al. (2007) and Spinuzzi (2002; 2012) understand genre as a dynamic system within which a range of repertoires and practices can be accommodated. Engineering educators can decide what to include or exclude in their e-portfolio from the full range of their practice and the regulated and regularised genres available to them. The genre ecology approach is useful in studies where there are wide textual ranges and variations – such as expert and non-expert texts in teaching and learning contexts. This approach is particularly relevant to researching textual practices in technical contexts, since verbal data are analysed within the larger framework of spaces, contexts, artefacts, and the dynamics of human interaction. In this framework, texts are not simply performed or communicated, they represent the subject's thinking through the representation of their teaching practice. In the case of engineering educators applying for tenure, one would not expect all candidates to have mastered an expert educational genre, but to be engaged in a process of learning this genre, and re-contextualising it in terms of their own engineering field and experience. An ecology of genres is likely to develop in such a context. There will be constant importing, hybridizing, and evolving of genres, although one would not expect the discarding of key features of the genre, such as reflection on practice, in a teaching portfolio.

A methodology for researching teaching portfolios

In practitioner research, there are intersections between research and practice, researchers and practitioners, which was the case in this study. The description in the sub-sections below explain the different strands of academic development work (in this case facilitating engineering lecturers' teaching portfolio development), and educational research (in this case a study of the completed – or almost completed – teaching portfolios with a view to understanding how engineering as socio-cultural context impacted the representation of teaching).

Facilitating portfolio development

The Cape Higher Education Consortium (CHEC), a body that coordinates the work of the four Western Cape-based universities in South Africa, offers regional short courses to academic educators on a range of topics in higher education teaching and learning, including short courses on teaching portfolios. Six academic developers who were employed by the four universities jointly offered two CHEC short courses to science, technology, engineering, and mathematics (STEM) university teachers on developing teaching e-portfolios. The first short course took place over a four-week period, and the second took place over a six-week period. Approximately sixty STEM participants (~15 participants from each university) enrolled in the short courses, attended regularly and completed (or completed a first draft of) a teaching e-portfolio. The course covered key concepts in higher education teaching and learning, such as the higher education context – and why it matters – critical reflection, learning-centred pedagogies, and constructive alignment. The focus of the short course was preparing a teaching portfolio and thus included topics such as different kinds of teaching portfolio, ways of building an e-portfolio, audience, purpose and context, writing a teaching philosophy, and selecting appropriate documentation of teaching and learning. The course used an interactive workshop format, combining short presentations with peer engagement and formative feedback.

The portfolios were assessed online approximately two weeks after the final session and each participant received feedback from at least two facilitators. The feedback was intended to help the lecturers improve their e-portfolios before submitting them to their academic departments for consideration for tenure, promotion, or for an institutional or national teaching award. After completion of the course, the facilitators continued to support participants in their home universities to improve and complete their teaching portfolios. This study focuses on engineering lecturers' teaching e-portfolios.

Researching portfolio development

The research reported on in this paper is part of a larger project on pedagogies in STEM disciplines and fields. The project was jointly funded by the South African National Research Foundation (NRF) and the Swedish Foundation for International Cooperation in Research and Higher Education (STINT). Team South Africa comprised six academic developers across the four Western Cape Universities. The research design for this study was an artefact-based analysis of the e-portfolios submitted by engineering lecturers across the abovementioned

universities. Twenty-four of the participants were in engineering (or engineering-related) programmes. One of the universities does not have an engineering faculty, but does offer related programmes, for example, in information systems and computer science. The e-portfolios of a physics lecturer and a lecturer in statistics were included in the study because they teach physics or statistics *for* engineering. Table 1 shows the participants, their engineering fields and the context of the teaching portfolio.

Table 1: *Participants, fields and contexts*

Portfolio	Engineering field	Context
1	Building construction	Teaching award
2	Building construction	Ad hominem promotion (senior lecturer)
3	Chemical	Teaching award
4	Chemical/polymer science	Tenure
5	Chemical/polymer science	Tenure
6	Civil	Ad hominem promotion (senior lecturer)
7	Computer	Ad hominem promotion (senior lecturer)
8	Computer	Ad hominem promotion (associate professor)
9	Electrical	Ad hominem promotion (associate professor)
10	Electrical	Ad hominem promotion (full professor)
11	Electrical	Ad hominem promotion (senior lecturer)
12	Environmental	Teaching award
13	Food technology	Teaching award
14	Mechanical	Ad hominem promotion (senior lecturer)
15	Information systems	Ad hominem promotion (senior lecturer)
16	Information systems	Ad hominem promotion (senior lecturer)
17	Information systems	Teaching award
18	Information systems	Ad hominem promotion (senior lecturer)
19	Physics (mechanical)	Teaching award
20	Process	Ad hominem promotion (senior lecturer)
21	Statistics (electrical)	Tenure
22	Systems	Ad hominem promotion (senior lecturer)
23	Systems	Ad hominem promotion (senior lecturer)
24	Transport	Ad hominem promotion (associate professor)

The portfolios were analysed to identify the features of their genre ecologies, after which the findings were synthesized by locating the genre ecologies within the portfolio-building activity system. As a researcher, I had access to all the portfolios, which were submitted as digital documents or as links to candidates' own websites. Other studies with portfolio course participants focused on teaching identities in different disciplines (Winberg & Pallitt, 2016) and on participants' perspectives on teaching portfolios and the portfolio-development process (Winberg et al., 2018). In this paper, the focus is on the e-portfolios themselves, with a view to understanding how the engineering socio-cultural context impacted the candidates' representation of their teaching practice.

Findings: engineering the teaching e-portfolio

The teaching portfolio has settled into a recognisable genre with five clear textual identifiers: 1) a statement of the author's teaching philosophy; 2) a description of the teaching context; 3) examples or descriptions of teaching practice and rationales for these practices; 4) elements of critical reflection on practice, and 5) the portfolio usually has appendices of evidence that are linked to the claims in the body text. All the portfolios had these generic similarities, but distinct differences were found in how the generic components were understood, resulting in different genre ecologies. It was expected that differences would be evident in the portfolios intended for tenure, promotion and awards on the assumption that tenure portfolio authors were novice while promotion and awards authors were more experienced educators. However, this was not the case. Novice and experienced subjects (i.e., tenure applicants and ad hominem applicants) produced similar teaching portfolios, while the award portfolios were significantly different.

Teaching portfolios for tenure/promotion: foregrounding the reward

In teaching portfolios for tenure or promotion, the object is to represent applicants' practice at the appropriate level of competence (lecturer, senior lecturer, etc.). Such portfolios are usually assessed by the head of department and members of the faculty, and often include a teaching and learning specialist. Teaching portfolios for tenure and promotion are 'high stakes' portfolios and, if the submission is successful, can have considerable benefits for the applicant. Of the 24 portfolios studied, the majority (18 portfolios) were submitted for tenure or promotion (tenure n = 3, senior lecturer n = 11, associate professor n = 3, and full professor n = 1). These portfolios were generally written in an impersonal style that was closer to that of

an academic engineering style of writing than an educational style. There was a predominant use of the passive voice, shorter and more succinct text, and a vocabulary that was more engineering-focussed than educational. In demonstrating their competence, the engineering academics showed how their teaching practice was aligned with the institutional or departmental mission and vision. They therefore drew on 'regulated' resources, such as the institutional website to provide an official version of the higher education context, rather than describe their lived experience of it. They introduced themselves formally (in the style of a covering letter for a job application) explaining their roles and responsibilities (sometimes in the third person). Candidates tended to describe their practice with reference to similar official documents, such a course or syllabus outline, teaching materials used (sometimes several files of teaching materials were included as appendices), and links to, or screen-shots of, their learning management system. Applicants were careful not to critique their institution or department. Reflection was usually understood as planning *for* practice (rather than reflection *on* practice), in other words, reflection was understood as planning towards improvement – and checklists, improvement plans and teaching syllabi for the next year were often included as the result of reflection or evaluation. Reasons why improvement might be necessary were generally absent. In some cases, the appendices contained a short list of references consulted, usually the references that were supplied during the training sessions, although some portfolios referred to articles in engineering education journals. More common than references were the inclusion of inspiring quotations, usually unreferenced. The appendices included lists of materials (a table of contents was usually supplied to guide the assessor), some analyses of students' feedback (often from standard student evaluation forms) and the candidate's CV or link to an academic site, such as ResearchGate.

The following example is typical of the style of introductions:

> The candidate received a Masters of Statistical Science in 2016 from [name of university] after 15 years in the corporate sector, entered academia in June 2016. Being a relatively new 'hybrid' academic, the candidate has allowed herself one year to focus on teaching, after which she will commence the PhD in July 2017. Her research interest incorporates statistics, finance and engineering in the context of South Africa. It is important to maintain a balance between teaching and research as this approach will positively benefit my students and my discipline at large (Portfolio 21).

Notice how the applicant shifts the focus away from teaching towards her research trajectory, having allowed herself 'one year to focus on teaching'. When writing about her

personal mission to find 'a balance between teaching and research' she slips into the first person and a more personal writing style – moving from a regulated to a more regularised discourse style.

The genre ecology of the portfolios for tenure and promotion (Figure 2) was generally strongly regulated, that is, institutionally-aligned; for example, including quotations from the institutional vision and mission, providing links to the departmental prospectus, and using official descriptions of the institution context (such as those found on the institutional websites). Images and videos of generic engineering students in non-specific laboratories were taken from the website to represent the context. Descriptions of practice were short and aligned with institutional or professional requirements:

> In this course there is a strong focus on professional values, ethics and governance. This is essential because the profession is moving towards strengthened codes of conduct, regulation and legislation. Thus the [engineering] qualification has an increased focus on professionalism and ethics (Portfolio 2).

In the above example, which is fairly typical of the promotion portfolios, teaching is explained in terms of the official curriculum, or of regulatory council requirements, rather than described in terms of classroom practice. Evidence of teaching claims was offered with reference to a subject Learning Management System, official curricula or syllabus documents and teaching materials.

Figure 2 shows the genre ecology of teaching portfolios for promotion, which were notable for their formality, use of official documents, uncritical view of the institution, lack of detail on context, and close approximation to an engineering, rather than educational, writing style.

The column labelled 'genre rules' indicates that the expected elements of the teaching portfolio genre were present: there was a teaching philosophy statement, a description of teaching context, a description of and rationale for the particular practices adopted, a reflective section and appendices of evidence to support the claims made. However, the focus across all sections of the portfolio was the expectation of tenure or promotion. Teaching practice was thereby largely obscured, and was represented in terms of official documents, curricula, or requirements.

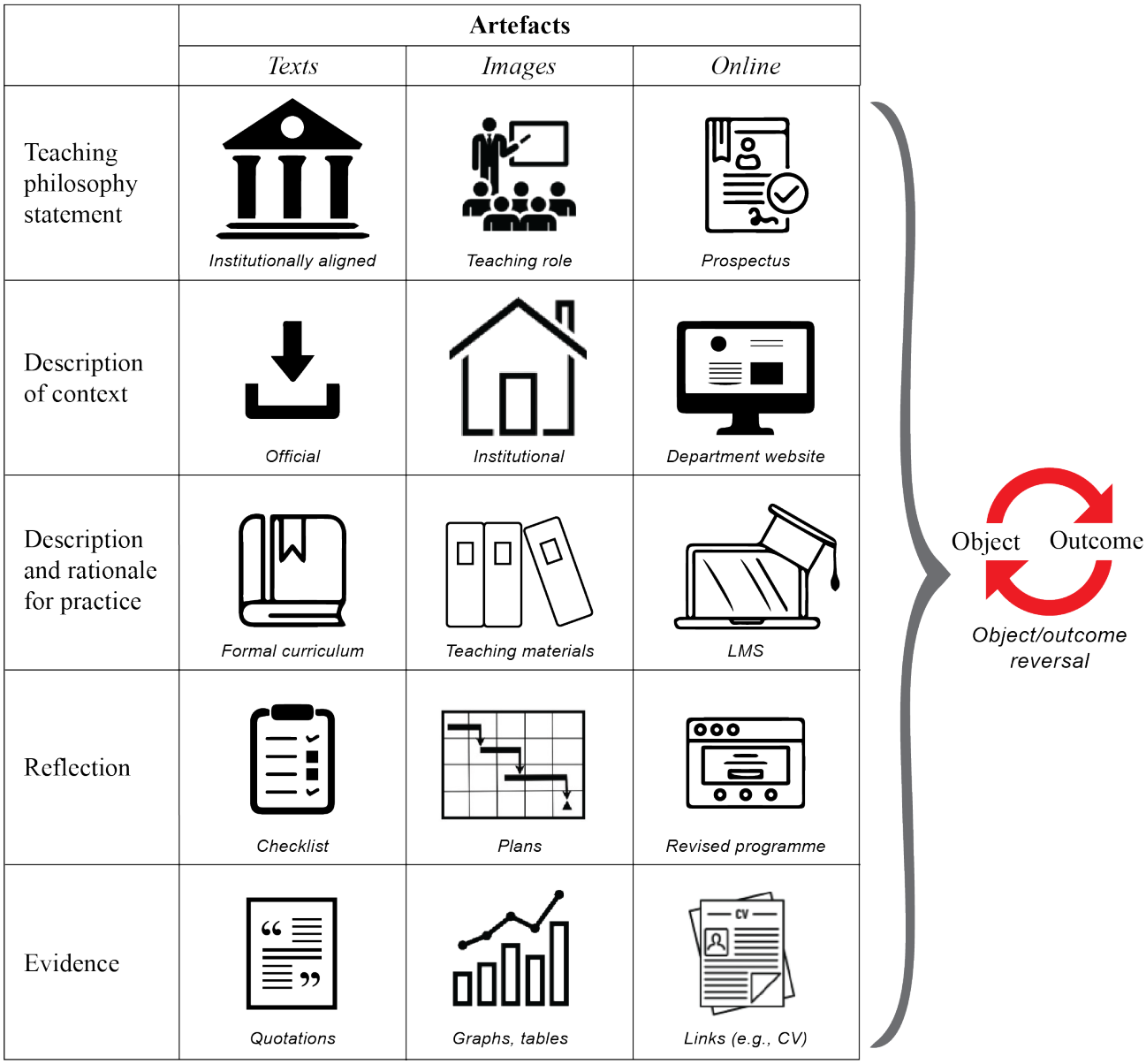

Figure 2: *Genre ecology of a tenure or promotion teaching portfolio*
Images source: https://publicdomainvectors.org

The object, which was to represent practice, was strongly impacted by the expected outcome, the award of tenure or promotion. What seems to have occurred in the tenure and promotion portfolios is that authors reversed the *object* of the system with the *outcome* to the extent that the object (representing teaching practice) was backgrounded and was supplanted by an object that represented the candidate's research trajectories, or professional requirements, possibly recognizing these as important in the social context of an engineering department. Engeström (1987) explains that object/outcome reversals are common in systems that are driven by rewards rather than by the development of subjects.

Teaching portfolios for teaching excellence awards: foregrounding teaching practice

There were far fewer portfolios (n = 6) submitted for teaching awards and, in contrast to the tenure and promotion applications, the portfolios submitted for institutional or national awards adopted a more personal and reflective presentation style. These portfolios had more heartfelt teaching philosophies, more detailed accounts of the candidate's role and responsibilities, and richer descriptions of the teaching and learning context:

> Our campus is one of the most culturally diversified in South Africa. Most of the students we receive are from the surrounding areas. They are disciplined and hardworking. Though they tend to undermine their capabilities, they have great potential when you provide them with proper guidance. They are very competitive as well because they do not want to be left behind by others. What drives me in teaching is the value that I add in making young people's life better. I believe that I am responsible for making our country a better place through a most powerful tool called education. I started teaching while I was in high school by helping my classmates when they didn't understand something and took over lessons when our teachers were late or absent, and that was not only limited at school – in sport and at church it was and is the same. I believe that teaching is in me. I see myself as a coach of a team who appreciates credit for the achievement of my students and take a blame for those who become unsuccessful and try to find remedies for their next attempts (Portfolio 13).

The above applicant strongly identified with teaching: 'teaching is in me' she explains, giving examples from other contexts. Here practice is foregrounded, not obscured. The focus on teaching practice, the rich descriptions of context (both the students' and her own), the candour, and her commitment to students were not seen in the tenure and promotion portfolios.

In addition to sharing personal information about their teaching journeys and future trajectories, the award applicants described – and theorised – their practice in richer detail, and with very little recourse to official documents:

> The core of my lesson plan, and discussed in greater depth in section 4, is a flipped classroom [reference] approach which encourages active, prolonged, positive engagement with constructs. Lecture time is repurposed into workshop sessions, and open and group debate and discussion is fostered. It is structured such that peer-to-peer, collaborative problem-solving is enabled (Portfolio 19).

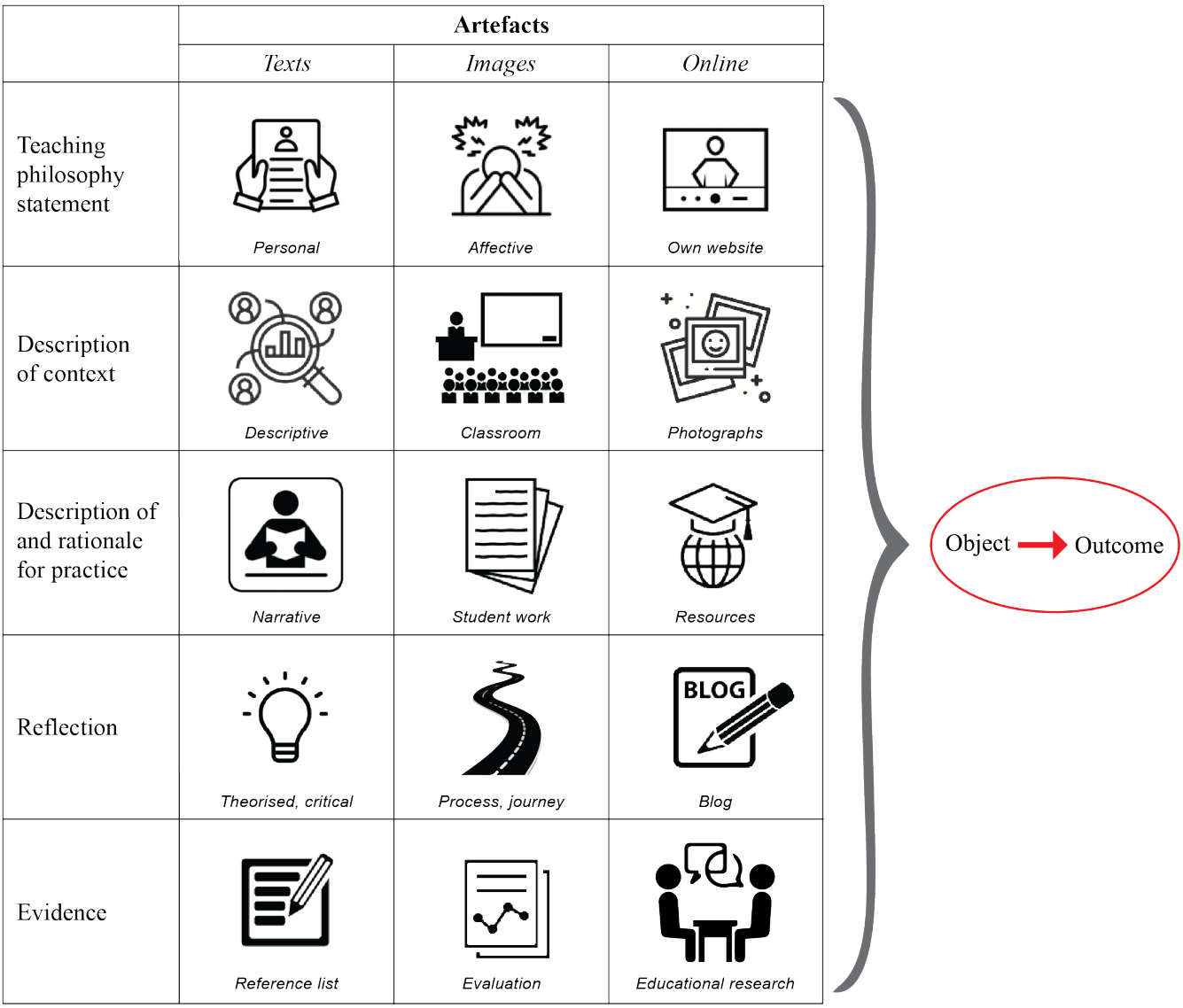

Figure 3: *Genre ecology of a teaching portfolio for teaching excellence awards*
Images source: https://publicdomainvectors.org

Although engineering discourse entered the description (e.g., lecture time being 'repurposed' and 'structured') it is predominately descriptive of teaching practice. Teaching portfolios for awards were reflective, drawing on the higher education literature and theory to frame teaching and learning decisions:

> I was inspired by the 'authentic learning' [reference] approach as it makes a sense in chemical engineering. I like to connect my students with actual workplaces. Students obviously learn outside of the classroom and I make use of this to make the connection with practice stronger. Linking what they are doing in the classroom with what they see in industry and having a discussion with a real engineer has been beneficial to my students… (Portfolio 3).

An award applicant explained his understanding of good assessment practice as follows:

> I learned that there is a theory behind rubrics (such as Bigg's Solo Taxonomy or Boud and Molloy's four characteristics of sustainable feedback) and I wanted to share this understanding with my own students. Thus students and I developed an assessment rubric together to help the students to become leaders in their own learning (Portfolio 1).

The genre ecology of the teaching award portfolios (Figure 3) was characterised by a personal writing style that combined narrative and theoretical modes, the use of photographs of candidates' own students (i.e., not from an institutional website), rich and detailed descriptions of the teaching and learning context (also accompanied by photographs), and theorised descriptions of the teaching approach used. Both formal (e.g., institutional evaluation forms) and informal (e.g., unsolicited emails) student feedback was included in an appendix or integrated into the text of the portfolio. Most portfolios included a list of references. In two cases, the applicants had published educational research, and included a link to their articles. The award applicants were clearly proud of their teaching achievements, as most of the award portfolios were online and widely accessible.

In contrast to the tenure and promotion portfolios, there was a clear focus on the object of representing teaching practice, and an expectation that the outcome would flow from the representation of a high standard of practice.

Discussion: unpacking the object/outcome relationship

Activity Theory tells us that the object drives the activity system, thus conflating the object and outcome is likely to cause 'contradictions' in the activity system (Engeström, 1999). Activity Theory views such contraditions in the activity systems as learning points. In this case the contradiction can be attributed to the high stakes nature of tenure and promotion. The high stakes context created tensions between an engineering and a teaching identity and led applicants to conceal their teaching practice rather than describing and reflecting on their practice. In the award context, the stakes were low (in comparison with tenure or promotion) and it was therefore unlikely that the social context of engineering would have as much influence.

The portfolios therefore fell into two groups: the award group portfolios were focused on the object of representing their teaching practice as theory-informed, student-centred and reflective, while in the tenure/promotion group teaching was represented in alignment with

institutional values and departmental goals. The difference between the portfolios that demonstrated reflective practice and those that demonstrated alignment with the department was their choice to foreground a teaching identity or an engineering identity: 'Professional identity is primarily regarded as a product of professional socialisation and training. This type of socialisation produces a strong resistance to 'external' intervention in the fabric of education' (Michelsen et al., 2017).

Thus in portfolios for tenure and promotion, the engineering identity was foregrounded and resistant to influences of the 'external' educational identity. In the teaching award portfolios the teaching identity was foregrounded and the engineering identity was, to a certain extent, backgrounded to accommodate the new identity. The tenure and promotion portfolios were not primarily written for an expert teaching audience, but for an audience who would judge it on its competence as understood in the departmental context.

The dynamics of how the activity system was reflected in each individual portfolio is unique. The tenure and promotions portfolios obscured teaching, but practice was not entirely invisible; the award portfolios foregrounded teaching, but an engineering identity was not entirely obscured. Thus while there were differences in portfolios for promotion and awards, these differences were complex and contingent upon the extent to which authors felt themselves enabled or constrained by the social context of the activity system. This sometimes made it difficult to fit portfolios cleanly into one or other category. Thus while the genre ecosystem of the teaching portfolio is strongly supportive of a teaching identity, it can also be transgressive and challenge accepted ways of being an engineering educator.

When items are more difficult to categorise precisely, a genre ecology analysis is particularly useful (Zachry et al., 2008). Locating an applicant along a continuum of revealing or concealing practice, for example through appropriate portfolio assessment rubrics, could help both academic developers and applicants to understand how their portfolios (and their teaching) could be enhanced. Portfolios for tenure, promotion and awards are inevitably different, but applicants, over the course of an academic career are likely to develop portfolios for different purposes and it would be helpful to understand the expectations of each, as well as how to meet their expectations more expertly by drawing on a more appropriate genre ecology.

Conclusion: implications for facilitating the development of teaching e-portfolios

The study addressed the research question: how does the social context of a teaching portfolio impact the representation of teaching practice? The genre ecology of a range of engineering educators' e-portfolios were studied in order to identify the different ways in which teaching practice was (or was not) represented in portfolios that were submitted for tenure, promotion or awards. That the object/outcome reversal drove differences in the portfolios was not an unexpected finding; what was unexpected was the strength of the differences. The differences between portfolios that expressed a stronger engineering identity and those that expressed a stronger educator identity were congruent with differences in reporting styles. The tenure and promotion portfolios were more compliant and formal; the award portfolios more reflective and personal. When the object and the outcome were reversed or conflated, the teaching portfolio tended to obscure teaching practice.

These findings have implications for academic development practitioners, engineering educators, and managers. More research is needed to find out how engineering educators could be supported in enhancing their teaching practice while demonstrating their development and growth in the process of applying for tenure or promotion. The study suggests, firstly that there is a need for academic developers, ad hominem promotions committees and applicants to develop a principled understanding of teaching trajectories at different levels. Academic developers could encourage applicants to draw more on their own experiences, rather than revert to compliance and the official website, while acknowledging the importance of alignment with a department's teaching and learning goals. Academic developers should accept discourse styles that might be more compatible with an engineering identity. Ad hominem committees could be made more aware of trajectories of teaching competence and consciously reward more reflective representations of teaching.

The study of the genre ecologies of the portfolios made the dynamics of the activity systems more visible, showing how the representation of teaching could be understood as an arena of conflict and tension between strong engineering and emerging educational identities. In Activity Theory these contradictions in the system are viewed positively as areas for change and growth. Activity Theory and genre ecology offered a way to systematically analyse these related sets of contradictions as we further examine portfolio development in increasingly complex, multidisciplinary higher education teaching practices.

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Application of a decolonisation framework to a second-year chemical engineering design project

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Following the student-led protests under the umbrellas of #RhodesMustFall and #FeesMustFall, several South African universities made efforts to transform their curricula to make them more relevant to a diverse student population. To this end, the research site for this study, a research-focused historically English-language university, revamped an existing project done by second-year students in their undergraduate chemical engineering programme. This article presents the application of a decolonisation framework to the revised project. Details about the project implementation were collected in the form of the project brief and the six tasks given to students; and semi-structured interviews were conducted with one course lecturer and one tutor. These details were supplemented with inputs from two authors involved in the project design and delivery. The article demonstrates that an engineering design project can be decolonised by increasing its relevance to the local context, valuing student voices in project design, providing opportunities to students for critical reflection, critiquing the existing engineering knowledge, and designing the project to be community-driven. The article specifically highlights the inadequacy of the existing engineering techniques for application in small-scale community-level projects, thus underlining the need for a broadening of engineering knowledge.

Keywords: chemical engineering, community-driven design project, decolonisation, South Africa, undergraduate engineering curriculum

Introduction

The student protests that started in South Africa in 2015 under the umbrellas of #RhodesMustFall and #FeesMustFall developed into one of the most important student protests in post-apartheid South African history, attracting the attention of the country's universities and national and provincial governments (Koopman, 2019). The #RhodesMustFall movement led to a successful campaign to remove the statue of Cecil John Rhodes overlooking the rugby

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field at the University of Cape Town (UCT), and grew into the nationwide #FeesMustFall protests. While the naming of the latter protests made for an easy association with the reduction in the cost of university education in the country, these protests also pointed to multiple forms of exclusion in South African higher education, and hence the urgency to address racial and gender inequities at the universities and decolonise curricula (Postma, 2016; Swartz et al., 2020).

In light of these protests, several universities took initiatives to work on the transformation and decolonisation of their curricula (Koopman, 2019). One such effort at the research site for this study, a research-focused historically English-language university, was to revamp the existing second-year project in the chemical engineering undergraduate programme.

This paper presents an application of a decolonisation framework to the new project. The goal of the paper is to provide engineering educators with an example of designing engineering courses and curricula from a decolonisation standpoint. This article provides details of the project implementation collected through course documents, such as the project brief and the six tasks given to students; and semi-structured interviews with one course lecturer and one tutor. In addition, the original intentionality of the project design is made explicit through details provided by two of the authors of this article. Although student interviews were also carried out as part of this project, those are beyond the scope of this paper.

Literature review

Grosfoguel (2007) notes that with the end of colonialism, the world moved toward a system of global coloniality, which is still present in the minds, psychologies, and worldviews of the then-colonised people. It ‘is maintained alive in books, in the criteria for academic performance, in cultural patterns, in common sense, in the self-image of peoples, in aspirations of self, and so many other aspects of our modern experience’ (Maldonado-Torres, 2007, p. 243) and manifested in the hierarchical relationships between those colonised in the past and their colonisers. In terms of knowledge, coloniality is manifested as an exclusion of indigenous knowledge and portrayal of the Western world as the only source of legitimate knowledge (Quijano, 2007; Smith, 1999).

Decolonisation, or decolonialisation as it is called by some scholars, is therefore not only an end of the territorial, political, and judicial subjugation of the colonised nation by the colonial

powers but is also the termination of the various racial, ethnic, gender, sexual, religious and, for the purposes of this paper, epistemic hierarchies imposed upon the colonised (Maldonado-Torres, 2007). Decolonisation of knowledge can thus be seen from a rejectionist perspective that calls for an epistemic disobedience by mobilising institutions and scholars to challenge the universality of Western conceptualisations of knowledge production and imparting (Chowdhury, 2021).

Decolonisation of curricula

The well-known decolonisation scholar Molebatsi Nkoane (2006) argues that decolonisation of universities and institutions is essential to make them more relevant to the African context. He notes that the African university 'needs to represent the African experience, ideas and finds its resources from within African culture' (p. 54). At the same time, the African university should also emphasise 'mental decolonization from stereotypes and strictures from the past, and mental emancipation for socially and communally engaged scientific projects' (p. 54). Nkoane further notes that mental decolonisation can be achieved by the African people by carrying out an analysis of who they are as people and how their minds and thoughts are controlled by Eurocentric discourses that are not always relevant to their contexts. Thus, Nkoane's notion of decolonisation of the mind resembles the idea of critical consciousness advanced by Freire (1970), who argued that education should empower students to think critically about their lives and situations. In other words, a curriculum should provide students with opportunities to reflect upon their life contexts so that they can recognise injustice in their daily lives, and then enable them to take action against these unjust practices and for social good.

In a summary of the recent debates on decolonisation of the curriculum in the South African national context, the Council on Higher Education (CHE, 2017) outlines four strategies to achieve the decolonisation aims. These include changing the course content, changing the delivery to increase access to higher education, changing the understanding of knowledge that is imparted in universities, and changing who is teaching or researching this knowledge. These four aspects of decolonisation are discussed below in detail.

In the changing of course content, the CHE emphasizes replacing the 'canons' of knowledge that are taught in the universities and are perceived to be Eurocentric with locally-

produced texts and works. Speaking of the presence of the Eurocentric canons of knowledge in the courses and academic degrees at African universities, Nkoane (2006) notes:

> Most modules and/or academic programmes (such as education, science, law, psychology, sociology, political science, law) in different disciplines at African universities are not anchored in or linked to African cultures and realities. The disciplinary problematisations, classifications, examples, illustrations, comparisons, models, social systems and structures, institutions, interpretations and misinterpretations, mistakes and solutions all come from Western realities and socio-cultural constructs. (…) African culture is often only brought up in passing (p. 62).

Similarly, Le Grange (2014) argues that locally-relevant curricula should be designed that move away from the domination of Western epistemologies and challenge the power relation between local and Western knowledge systems. He also advocates for teaching students about the achievements of people in the African continent. He argues that such an understanding can help students free themselves from the dehumanisation that is imposed on them by the Western world. While the change in the canons suggested by the CHE (2017) may mean studying the texts and works produced by local authors in humanities and social sciences, in the natural sciences and engineering, this change may refer to the use of local examples to understand scientific concepts and using scientific knowledge to address problems situated in the local context.

Several educators have previously substituted the existing Eurocentric content with work from other parts of the world. For example, while teaching a thermodynamics course to second-year chemical engineering students at a US university, Riley (2003) gathered resources on inventions such as the still, perpetual motion machines, and underfloor heating in Asia, Africa, and the Arab world and incorporated them in her course. Another example is the approach taken by the Intercultural University of the Indigenous Nations and Peoples, Amawtay Wasi, in Ecuador. In this approach, the pathway to learning at the university follows three stages: the cycle in the formation of ancestral sciences; the cycle of western sciences; and the cycle of interculturality. One of the objectives of this pathway is to help students gain an intercultural education that accepts the diversity of knowledges of the indigenous nations (for a detailed discussion, see DeCarvalho and Flórez-Flórez, 2014). Similarly, instead of discussing Euro-American canonical theories, Morreira (2017) asked her students in a first-year undergraduate social sciences course to read the works of Steve Biko, a South African anti-apartheid activist, to help them learn about the psychological damages inflicted by apartheid on the Black

population. In the field of therapy, Diab et al. (2020) provide empirical examples of modifying the curriculum of psychotherapy and family therapy to address the specific needs of traumatized individuals in the war-torn Gaza Strip.

As regards to changing the delivery of course content, the CHE (2017) argues for debunking the idea of a decontextualised student who is independent of what is taught and learned. Noting that students are social beings who construct an understanding of the reality around them through their experiences, the CHE stresses that knowledge, if presented as a set of value-neutral skills to be learned, can be colonising and alienating for students. It further suggests, '[d]ecolonisation would therefore require deliberate attention to surfacing, and inducting students into, specific forms of meaning-making, with a move away from thinking of curriculum as something received, but rather as a co-constructed set of understandings' (p. 5). By actively engaging the student in the process of knowledge construction, the delivery can increase their access to the knowledge and the relevance of what is learned. These arguments about delivering the course knowledge in a such a way that allows students to be active participants through dialogue and interaction are also advocated by Freire (1970). Drawing on Freire's work, Swartz et al. (2020) also note that a problem-posing education that helps students reflect on the causes and circumstances of their lived experiences, and learn how to transform their lives, is at the heart of decolonising pedagogy. This kind of education necessitates students to engage in praxis, i.e., critical reflection and action based on it to transform the world (Freire, 1970).

Riley (2003) demonstrates how students can act as active participants in knowledge production by asking them to reflect on how thermodynamic principles can be applied to phenomena around them in their everyday lives. Similarly, Padilla (2021) documents engaging students as active participants in learning by asking them to build a greenhouse using indigenous mathematics and, in the process, critically explore the indigenous worldviews in Colombia. Students were also asked to take measurements using their hands as measuring instruments. Parker et al. (2017) demonstrate the practice of engaging students as active participants in knowledge production in a decolonising research methodologies course in the US by asking them to work collaboratively with other students and apply critical reflexivity to construct their course understanding, while the instructors acted as facilitators.

To change the understanding of knowledge, the CHE calls for critiquing the dominant conceptualisations of knowledge in the university. It notes that such current conceptualisations, which are also primarily Eurocentric in nature, are based on a Cartesian duality, which separates knowledge from the knower (Quijano, 2007) and posits that one can only know about reality by being a detached knower. As Thaman (2003) writes, however, decolonising knowledge treats alternate ways of seeing the world as legitimate. Le Grange (2014) argues for moving beyond mere observation and listening as the only legitimate ways of knowing to also recognising knowing 'through the tastes, pain, and hunger of their bodies and through expressions of anger, passion and desire' (p. 1289). Summing up these arguments, Mbembe (2016) notes two aspects of decolonisation of knowledge. The first is to critique the production of knowledge and theories that are based on European or Western traditions. The second is to imagine and develop an alternate model of knowledge production.

Riley (2003) provides an example of critiquing the dominant conceptualisations of engineering knowledge in the university. While teaching an undergraduate thermodynamics course, she asked students to critique the textbook used for the course with a focus on the kind of examples the book used and the kinds that it excluded. Through class discussion with her students, they concluded that the book did not sufficiently include energy systems in developing countries and environmental applications of the theories of thermodynamics. She also highlights the uncertainty in the laws of thermodynamics, thereby critiquing the perceived objective nature of scientific knowledge. In the South African context, Conana et al. (2016) give an example of presenting knowledge in physics in a modified way that treats physics knowledge as less detached and hence more accessible and relevant for students. They show how the teaching of physics can be made less alienating by: presenting physics as a process, rather than a discipline, that is used to model and predict the physical phenomena around us; focusing on how scientific knowledge is constructed; contextualising physics knowledge in the wider social, political, and historical contexts; and presenting physics as a way of knowing along with other systems of knowing. Beyond science and engineering, Morreira (2017) asks her students in her social sciences course to critique the different conceptualisations of Africa in the literature. Moving beyond observation and listening as the modes the learning, Wong (2018), while teaching a postgraduate social work course in Canada, notes incorporating mindfulness in classroom by asking students to work with and learn from their emotions and feelings.

Finally, in addition to whose knowledge is taught, how it is viewed, and how it is taught, the CHE (2017) draws attention to who is teaching or researching the knowledge. It argues that the African experience can only be reliably and authentically communicated by Africans, as assuming that others can communicate the African experience would mean that experience is transferable (Nkoane, 2006). Along similar lines, Le Grange (2014) argues for including ordinary citizens from the indigenous communities as agents of knowledge production.

A prominent example of changing who is teaching the knowledge is the 'Meeting of Knowledges' project implemented at universities in Brazil and Colombia (DeCarvalho & Flórez-Flórez, 2014). As part of this project, masters of traditional knowledges, such as artisans, healers, shamans, traditional architects, and performers were invited to the universities as visiting professors to teach courses in architecture, music, theatre, health, and environment. Prior to beginning their teaching, these masters did an internship in which they listened to the regular classes to learn about the pedagogical practices in the university. Thus, this effort infused the teaching of traditional knowledge with the pedagogical practices at the university. Similarly, Parker et al. (2017), in their course on research methodologies, talk about bringing community experts into the classroom to discuss their work and collaboration with the academics. Saurombe (2018) documents the process of changing knowledge production by encouraging archivers and academics to work together to learn about and create a history of decolonisation of higher education in South Africa.

Decolonisation as an option

While it is important to engage in conversations on decolonisation and take effective steps to achieve this goal, it is important to note here that decolonisation, like the imposition of the colonial and modern hierarchies, cannot be imposed on people. It can be achieved only when people engage in dialogue about what it means to decolonise and envision a world that is based on and constituted through a co-existence of diverse epistemic positions (Maldonado-Torres, 2007). Imposing decolonisation on people like the imperial modernity would be akin to imposing a new form of coloniality on people, renamed decolonisation. Mignolo and Walsh (2018) emphasize that decoloniality is not an end in itself. Rather it is an option along with other options of living and being in the world and should be adopted through praxis, i.e., critical reflection and action on the world to transform it (Freire, 1970).

In line with these arguments, scholars working on decolonisation of curricula do not advocate for a complete removal of the Western and the European canons of knowledge. Rather, they call for an infusion of the Western knowledge systems with the indigenous ones such that 'one knowledge system is not viewed as superior (Western) and other as inferior (indigenous)' (Le Grange, 2014, p. 1292). Similarly, for Mbembe, a decolonised university accepts and embraces '*a horizontal strategy of openness to dialogue among different epistemic traditions'* (Mbembe, 2016, p. 37, italics in original). Thus, what is being advocated is not a rejection of the Western traditions of knowledge production and the already existing theories, but rather a shift in the exclusive focus on the Western traditions to juxtaposing them with the African ones. Ndlovu-Gatsheni (2013) calls this a democratisation of knowledge in that it recognises knowledge from other parts of the world that were once colonised as equally important and relevant.

Resistance to decolonisation of curriculum

While decolonisation provides a viable approach to democratising curriculum and higher education in general, this idea also faces several challenges and resistances in its implementation. The first and foremost challenge to decolonising curricula in science and engineering (which derives extensively from scientific knowledge) is the attitude to the nature of knowledge. Given that the scientific knowledge is largely seen as universal, decolonisation of science and engineering curricula is often disregarded by academics (Blackie, 2019).

The second challenge stems from neoliberalisation of the university. Koopman (2019) argues that the neoliberalisation of the university in South Africa has led to an emphasis on performativity of staff and students in terms of completion of syllabi and attainment of learning outcomes as a measure of success. While this style of management of universities has emphasised training students for the workforce, it has limited for students the 'space for critical thinking and self-directed learning, and to be playful partners in the knowledge construction process' (p. 58).

The third resistance to decolonisation comes in the form of pressure to internationalise higher education. Universities across the world, including those in South Africa, face a pressure to internationalise and compete in global rankings, thereby reproducing curricula and university structures that are Westernised (Knight, 2018; Mbembe, 2016).

The fourth challenge to decolonising engineering curricula is posed by a lack of resources needed to design context-relevant curricula. Senekal and Lenz (2020) note that a significant challenge to decolonising the curriculum in South Africa is the lack of resources in terms of content and time to work on changing the curriculum.

The fifth challenge to decolonising engineering curricula comes from students and academics, including the university leadership. Students often see a localised engineering curricula as something that can impede their career mobility in a globalised engineering workplace (Fomunyam, 2017; Winberg & Winberg, 2017). At times, students also resist an engineering curriculum that pays attention to background and contextual details with a preference for hands-on activities (Winberg & Winberg, 2017). Similarly, several academics 'are content with the status quo and prefer to deal with the devil they know rather than the one they don't' (Senekal & Lenz, 2020, p. 157). This resistance from academics and the institutional leadership continues to perpetuate the colonial hegemony in the curricula (Chowdhury, 2021).

Finally, in South Africa, language poses a severe challenge to decolonise learning with the language of engineering instruction being English or Afrikaans. While there have been movements against Afrikaans as a medium of instruction in universities, the presence of English still creates a barrier to learning for a majority of students in the country who do not speak English as their first language (Dube, 2017). Students in the study conducted by Fomunyam (2017) noted that English as a medium of instruction not only makes learning difficult but also many 'students fail because of this hard language' (p. 6801).

Given the complexities of decolonising an engineering curriculum in light of the nature of the disciplinary knowledge, pressures to internationalise, and resistance from students and academics, Winberg and Winberg (2017) advocate an engineering curriculum that brings together the traditional curriculum with aspects of decolonisation. This curriculum is designed to cater to African needs and has a strong focus on the historical, social, and cultural studies of engineering to help students understand the roots of engineering knowledge. In addition to an internationally recognised qualification and attainment of graduate attributes, it also includes understanding ethical and environmental considerations, valuing diversity, and a focus on the African continent. At the same time, the curriculum proposes the need for taking inputs from

the broader communities that would be affected by engineering work and fostering partnerships with the local industries.

Applying a decolonisation framework to a chemical engineering course project

While there is a growing interest in decolonising the curricula in engineering, there is limited scholarship on its implementation. This paper aims to address this gap by providing an example of decolonising an engineering project taught to second-year students pursuing chemical engineering. It is hoped that this example may provide a model to engineering educators who want to decolonise their teaching and courses.

As noted earlier, following the student-led protests in South Africa, several universities made attempts to decolonise their curricula. To this end, the research site for this study, a research-focused historically English-language university, redesigned the chemical engineering project done by students in the second year of their undergraduate degrees.

The description of the project presented here is constructed on the basis of an interpretivist paradigm using qualitative data. This paradigm was chosen because the project description presented here was co-constructed by the authors in accordance with their interpretation of the decolonisation literature and the details of the project. The sources of data included: 1) course documents such as the project brief and the six tasks that were given to students; and 2) in-depth semi-structured interviews with a course instructor (who was deeply involved in the design of the project), and a course tutor who worked closely with students and the instructor when the project was rolled out. The course documents provided the specific details about the project design and assignments given to students during the project. The interview questions focused on eliciting the key features of the project, the reasons for changing the project, how the project met the goals of decolonisation, and the experiences of the instructor, the tutor, and the students with the new project. Thus, the interviews provided the context and background for the new project. In addition to these two formal modes of data collection, details about the project were also provided by two authors of this paper through the process of discussion and reflection – one of them served as the convener for the project and another was deeply engaged in the design of the project.

The course documents and the interviews were analysed through thematic coding in line with the four strategies outlined by the CHE (2017) as *a priori* categories (i.e., change in the

course content, change in delivery, change in understanding of knowledge, and change in who is teaching/researching knowledge). The four strategies suggested by the CHE were chosen for analysis because of their relevance to the South African higher education context. The analysis was done as recommended by Miles et al. (2014). Initially, the first author read through the data to identify aspects of the project that aligned with the *a priori* categories. During the analysis process, one of the *a priori* categories (i.e., change in delivery) was modified to include three subcategories that emerged from the data. The identified excerpts along with their categories were then shared with the other authors to check for disagreement. Any disagreement in the coding was then resolved through elaborate reflective conversations among the authors. An initial draft of this paper was also shared with the course instructor, who was interviewed earlier, to check for any misalignments in the project details. No disagreement was reported.

The following sections first explicate the context and key aspects of the new project and then discuss how the project design and delivery aligned with the four strategies outlined by the CHE (2017). Excerpts from the course documents and quotes from the interviews are provided as evidence for the arguments made. This work was approved by the concerned Faculty's Ethics in Research Committee at the UCT.

Context of the new project

Since the rollout of a renewed chemical engineering curriculum at the university in 2014, the curriculum requires students to do semester-long design projects in each semester of their second and third years. From 2015 to 2018, the project in the first semester of the second year was industry-based in that it dealt with the design of a large petrochemical plant. The students were required to synthesise a precursor for the production of polymers using refinery products. The project addressed both technical and economic aspects of designing and running the plant, and the project goals were aimed primarily at increasing the overall revenue generation in the process. The only direct connection of this project to the local context was evaluating the potential impacts of running the plant on the nearby town in case of an unforeseen and catastrophic event.

To address the issue of the course project being somewhat removed from the local settings, a new project was introduced in 2019. This project, designed with the aims of decolonisation in mind, involved an analysis of several aspects of the treatment and use of biogas produced

by an anaerobic digester to be installed in an informal urban setting, viz., a food market near a transport hub and urban farming centre, on the outskirts of the city where the university is located. Feed materials to be considered were human excreta, slaughter wastes and garden wastes. The project ran for a full semester (12-13 weeks) with an expectation that students would spend 4-5 weeks on the project task. The remaining weeks were devoted to learning the theoretical concepts required to execute the project.

A community-based organisation (CBO) was seen as the driver of the project, with the teams of student engineers acting only as project consultants. The members of a CBO typically include a community leader who is a respected and influential member of the community, and community activists who are committed to the actions required to bring about change in their communities. Based on the experiences and observations of one of the authors in their interactions with CBOs, the CBO leader(s) and activists foster close ties with the members of their community, community policing forums, public services (e.g., libraries, childcare centres, clinics), religious leaders, ward councillors and other key members of the community. Owing to the logistical and financial constraints of finding and compensating a CBO willing to invest the time and effort to provide an educational framework to students, the project incorporated a CBO through role-playing members. The instructors and the tutors, who acted as CBO members, had considerable knowledge and understanding of the local community in which the project was located through either their lived experiences, or through reading the works of those who had worked in similar communities.

Change in the course content

One of the most significant changes that was introduced in the new project was the incorporation of a locally-relevant problem. As noted earlier, the new project required students to work on the treatment and usage of biogas produced by an anaerobic digester situated on the outskirts of the city. Thus, the project moved the site of engineering learning from an industrial setting that was far removed from the experience of most students to a local setting that was familiar to a greater number of students.

Some students would have grown up or lived in a similar community and thus had lived experience of the project context. However, even for those who had not, the presence of similar communities around the city meant that most students would have travelled past this or similar localities while commuting to and from the university and around the city, and thus would have

had a point of reference to the locality and community in which the project was based. The familiarity of the project context was highlighted by the course instructor during the interview:

> To what extent … is a portion of the class that comes from socially disadvantaged backgrounds, from the types of backgrounds we want to benefit from this, it seemed to me there were people in [the] group that had that relation, emotional or direct through family where they had personal experiences to that.

Furthermore, the raw material inputs to and uses of the outputs of the biogas plant that was to be designed as part of the project were anchored in local experience and culture. An anaerobic digester generates biogas as its main output product from the surrounding waste streams as input material. Starting from the beginning of their work on the project, students were asked to consider the productive use of wastes and biogas in the local context. For example, the first project task asked them to 'give consideration to the **productive** uses of waste and energy (biogas) in an **urban informal** and in an **African** setting' (bold in original). Students were specifically asked to consider (amongst other potential uses) how: (i) a chicken vendor might utilise the biogas for boiling water to pluck chickens; and (ii) a brewer might use the biogas to brew *umQombothi* (local beer). It was anticipated that manumqy students would be familiar with braaied (barbecued) chicken and/or *umQombothi* as they are rooted in local culture.

Finally, the task and project deliverables were intended to move beyond just an academic document and were rather designed to be useful documents intended for use in real-life scenarios. For example, the deliverable of the first task was an infographic whose purpose was to effectively facilitate presentation, communication and discussion with the local community. The final deliverable was a coherent report of the work done to date that could be leveraged in a proposal for the ward councillor or a document with the detailed design and costing that could be used as a framework for soliciting contractors to apply for tenders.

Change in the delivery

The second significant way in which the new project met its decolonisation goals was the change in the way it was delivered to the students. The CHE (2017) emphasises the need for incorporating delivery modes in the curricula that position the students as active participants in the process of learning, thereby increasing their epistemic access to the knowledge in

question. The new project intended to achieve this in three ways: valuing student voices; developing critical awareness in students; and incorporating new sites of project delivery.

Valuing student voices: to increase the epistemic access of students to the knowledge that is expected to be co-constructed in the teaching and learning process, it is important to listen to their voices in the design and delivery of the course materials. To this end, during its design phase, the new chemical engineering project at the research site addressed the students' critiques of the old project. One major critique from the student body was that, after introduction of the social and the environmental impacts of engineering in the first year, the old project abruptly narrowed its focus on the technical and environmental aspects of chemical engineering work. As the course instructor noted during his interview:

> In this course in particular, we had gotten quite a bit of critique from the student body in the years of the challenges on what the university is and how it operates, that the first year had set up an expectation of chemical engineering employed for environmental and social good. The first-year projects all are forward-looking and [involve] an environmental impact, typically: biofuels, hydrogen, water projects… and then second year, they go in and it's like 20th century industrial chemistry… and there's nothing left of this intent.

The new project addressed this critique by situating the project in a local community, and at the same time focusing on the social and the environmental causes of producing energy through waste management.

Developing critical awareness: another significant way in which the new project engaged students in the process of learning was to provide avenues for them to critically engage with the course material through reflection exercises. For example, in the first project task, students were asked to name and critically reflect on their 'inherent biases and assumptions [about] the project context' while reflecting on their 'role as an external agent' in the community and the project. It was hoped that students would be able to engage in productive discussions amongst themselves, leveraging their existing contextual knowledge, to acknowledge and challenge their assumptions.

Similarly, in the sixth and the final task students were asked to 'discuss the social considerations associated with AD (anaerobic digestion) and products in the context of this project, with reference to the process/product options and how they relate to and/or build on the assets of the community identified at the beginning of the project' (Project Task 6).

Additionally, they were asked to reflect on their learning through this community-driven project. Amongst other topics, they were asked to focus on: (i) their roles as future engineers in community spaces; and (ii) the application of chemical engineering knowledge at community scale (vs. industrial scale). The rationale behind asking students to reflect on this aspect was to enable them to imagine their future professional roles in a local context that could serve local needs. Thus, by providing opportunities for critical reflection on the disciplinary knowledge and their roles as future professionals, the project moved away from treating students as decontextualized learners to active participants in knowledge construction.

Changing the site of delivery: another way in which the new project aimed to improve students' access to knowledge was through change in the site of delivery to the site of the project. While traditionally teaching and learning mostly takes places within a classroom setting, the project sought to disrupt this idea by including on-site classes in its initial conceptualisation. It was hoped that through reimagining and expanding the possible sites of teaching and learning to locales more familiar to students, the learning that happened would be more contextualised for students, thereby increasing student access to knowledge. Unfortunately, these off-campus sessions were not included in the final project delivery as the class consisted of more than 100 students and it would have required significant time, cost, and coordination efforts to take these students to the project site.

Change in the understanding of knowledge

The third way in which the new chemical engineering project at the research site addressed the goals of decolonisation was by critiquing existing knowledge and theories and exploring the possibilities of change in understanding of the disciplinary knowledge. As noted above, the new project aimed to connect engineering learning with the lived experiences of the students. To this end, the engineering methods that were used to complete the project also changed in that they focused on applying engineering concepts and theories to the problems situated in the local community context. The process of changing the conceptualisation of knowledge also highlighted the gaps in the current canon of engineering knowledge. As the course lecturer and the course tutor highlighted in their interviews:

> Let's stick with a more practical view here of how do we do a project in a second year that brings the South African context into the project. That's the main bit. And thereby possibly

> challenge the engineering methods our students learn [and] whether [these] can work in such context. (Lecturer)

> The [project] scope remained the same in the case of the key result areas with the experience students do get, but I think the concept changed. [Thus, the new project addressed] that issue of decolonising science and trying to introduce concepts to students which were Africa-based or community based. (Course tutor)

It was realised that while the existing knowledge is adequate for addressing large-scale industrial problems, it is inadequate when applied to a small-scale community project. As the course lecturer highlighted:

> Because the plant was so much smaller than if it had been an industrial plant, all of the wonderful heuristics that are used were out of range…. And so indeed there's a vacuum of engineering methods at community scale work. And that's an important finding actually of this piece of work.

On this issue of knowledge gap, the lecturer also added that one of the important aspects of decolonisation is to develop knowledge and techniques that are suitable to solve the problems of the community in which the engineering work happens. Hence, if engineering work is to happen in a semi-urban community (as was the case with the new project), engineering knowledge that can be adequately applied to solve the problems in that community must be developed.

Change in who is teaching/researching knowledge

The fourth and final way in which the new project addressed the issue of decolonisation was by bringing about a shift in who teaches and researches knowledge. As noted earlier, the primary driver of the project was the CBO situated in the local context. The CBO was positioned as the key knowledge holder that provided enabling inputs to the students throughout the project tasks. The CBO also steered the direction and focus of the students' contribution. The students working on the project only acted as consultants to serve the CBO and the community by providing expertise that was relevant and tailored to the context of the local community, through collaboration with the CBO. The aspect of the students working as consultants was emphasised in the first project task:

> Your first task is to provide a concept note (i.e., a literature review with contextual interpretations) to the CBO on AD [Anaerobic Digestion], including: information about the

> technology; health, safety, environment and economic considerations; and social impacts of the project.… The CBO have asked that you present the information as a poster such that the whole community is able to engage with the information and comment on the possible project.

The subsequent tasks were also designed and worded in a way that emphasised the role of the CBO as the driver of the project and the students as consultants. For example:

> The CBO thanks you for the poster you presented.… However, the poster session also made the community aware of two other issues that could potentially impact on the success of the project. The first is the cost of the storage vessels for the biogas and biomethane…. The second is the safety considerations associated with the handling and storage of biomethane…. Thus, the CBO would like your team to investigate and report on the storage and safety issues. (Project Task 2)

> From the previous task undertaken by the consultant teams, the CBO is now of the opinion that the liquefaction of biomethane (for use as a vehicle fuel) is too capital- and energy- (operating cost) intensive. This leaves two options still under consideration, either:
>
> (i) the use of raw biogas for cooking; or
>
> (ii) upgrading of the biogas to biomethane for electricity generation (in a gas turbine).
>
> Thus, the CBO would like your team to investigate and report on the health, safety & environmental (HSE) and energy implications of these options. (Project Task 4)

In addition to the project tasks being driven by the needs and considerations of the community, the feedback given to the students was also from the perspective of the CBO partner.

The process of positioning the community as the driver of the project was also supported by challenging students to adopt an asset- rather than needs-based mindset, as suggested by Mathews (2013). An asset-based approach positions the community members as drivers of initiatives aimed at their own development. In this paradigm, students identified (with the help of the CBO) the human and material assets of the community and considered how these could be put to use in the process, rather than focusing on the perceived needs (or shortcomings) of the community and doing technical analysis on an imposed solution. For example, for the first task, informed by the reading and their discussions, the student teams were asked to engage in discussion with the CBO to assist them in reaching a common understanding of their respective roles; elements of the project that supported an asset-based approach; and specifically, how to measure and monitor the impact of their work.

By positioning the CBO as the key knowledge holder and the project driver, the project explored the possibility of teaching engineering and doing engineering work through a dialogue with the community that was directly impacted by it. Additionally, it opened up the engineering space for a group of people who, despite being key stakeholders, usually have little say in how engineering projects are designed and executed. Thus, by expanding who gets to have a say in the engineering teaching and work, the project changed who can teach or produce engineering knowledge.

Discussion

The new chemical engineering project introduced at the research site aimed to decolonise the teaching of the discipline by changing the project context, delivery, and the individuals involved in teaching of the project. The project situated the problem that was solved by the students in the local context of an informal urban settlement in line with the recommendations by the CHE and other decolonisation scholars (such as Le Grange, 2014; Winberg & Winberg, 2017). Thus, it brought the context and setting of the project from that of industry (far removed from most students) to one that was more familiar to students, both in terms of lived experience (for some students) and, through regular visual/physical proximity, point of reference of locality and community (for most students). Moreover, by keeping biogas at the core of the project, both the raw material inputs (domestic, small-scale farming and market wastes) and the uses of the products (biogas as well as liquid residues) were anchored in local experience and culture.

In the process of changing the delivery, the project also adopted a Freirean approach to education by developing critical awareness in students through critical reflection exercises and discussions about: (a) their inherent biases and assumptions about the project context; (b) the social considerations associated with the project itself; and (c) their learnings from the project (with an emphasis on their work as future engineers). Thus, the project enabled students to become active participants in knowledge construction rather than being passive recipients of the information (CHE, 2017; Freire, 1970). At the same time, the new project incorporated critiques from the student body, thereby valuing a dialogical approach to education, which is central to a Freirean and decolonising pedagogy (Swartz et al., 2020).

Going beyond situating the project in the local context and engaging students as active participants, the project sought to position the community members as knowledge holders,

contributing to the goal of decolonisation by changing who is doing the teaching (Le Grange, 2014). The project helped students learn from the experiences of the local community by creating a dialogical space between the students and a CBO that was the primary driver of the project. This community-centric approach of the project was also evident in challenging students to adopt an asset-based approach (Mathews, 2013). This aspect of the project design is along the lines of engaging the community in the process of knowledge creation and teaching, which has been advocated by different decolonisation scholars (such as DeCarvalho & Flórez-Flórez, 2014; Parker et al., 2017; Saurombe, 2018).

One interesting and significant outcome of changing the focus of the project from large-scale industrial needs to community needs was that it highlighted the gaps in the current canons of engineering knowledge and particularly the inadequacy of this knowledge (and the information readily available in standard texts) when applied to a small-scale community project. This finding opens up the discussion in relation to what constitutes engineering knowledge and what the domain of engineering work is, thus opening up the possibilities for reconceptualising the disciplinary knowledge to address the goals of decolonisation (CHE, 2017; Mbembe, 2016; Morreira, 2017; Riley, 2003). This should not be seen as an 'either/or' problem, as large-scale production of goods and services is a requirement of both the developed and the developing world, and hence there is a need to create an avenue for different knowledge traditions to co-exist (Mbembe, 2016). To this end, while the project still addressed commercial concerns to help students prepare for industrial jobs, this was balanced with the broader contributions by – and benefits to – the community. Hence, it is acknowledged, and argued here that engineering knowledge should be expanded to include tenets that can also be applied to local small-scale community-driven projects, as previously advocated by other scholars (e.g., Le Grange, 2014; Nkoane, 2006).

While the project met several aspects of decolonisation, there were also difficulties in operationalising the changes needed to facilitate decolonisation. First, the initial project design sought to move the site of delivery from the classroom setting through site visits to provide even greater context for their work, thus moving away from treating students as decontextualised learners to active participants engaged within the project context (CHE, 2017; Freire, 1970). However, due to concerns about student safety and resource constraints, these off-campus sessions were not included in the final project delivery. Similarly, due to logistical and financial constraints, actual community members could not be brought in as project drivers, and instead course instructors and tutors role-played the members of the CBO. These

challenges pose a resistance to decolonising the curricula due to resource constraints (Senekal & Lenz, 2020).

Conclusion

By applying a decolonising framework to a new second-year design project in the chemical engineering undergraduate programme of a South African university, this paper has demonstrated that engineering design projects can be developed to decolonise the thinking of engineering students and teaching staff, by purposefully, and in a consultative way, adjusting the focus, context, and location of these projects. Challenges still exist in the implementation of such projects, principally in the logistics of creating interactions between the students and communities within the constraints of the programme. However, this work provides an example of epistemic disobedience (Chowdhury, 2021) in the field of engineering education, where decolonisation is often disregarded due to the perceived universality of the disciplinary knowledge (Blackie, 2019). The authors hope that the work presented in this paper will provide an initial example and a model for those engineering educators who aim to decolonise their engineering teaching.

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Engineering Education Research for educational change: the possibilities of critical realism for conceptualising causal mechanisms in education

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Engineering Education Research (EER) grew in prominence from the late 1990s as purposes for this field were espoused in relation to the necessity of change for engineering education in the newly globalising world. Arguments centred on overall challenges with recruitment to engineering, specifically in relation to historically underrepresented populations, as well as with the forms of education (both in terms of quality of teaching and relevance of curricula) offered to students, and the needs of employers as reflected in newly-emerged global accreditation systems. In a field that is at least partly directed towards educational change, there is a need to understand how change typically happens in education systems. This article first draws on findings from the sociology of education to show that causality in relation to educational change is complex. It then turns to the philosophy of critical realism for a way of thinking about change that can inform EER, and concludes by outlining how this might change the research questions that drive the field, and how these might be approached.

Keywords: educational change, critical realism, causal mechanisms

Introduction

While the first published research on engineering education dates to the early 20th century (Strobel et al., 2008), it is around the start of the 21st century that those doing this research started to formulate explicit statements on its purposes and scope (Klassen & Case, 2022). Much of this kind of writing first emerged in the USA, where significant investment by the National Science Foundation led to growing prominence for a field now with an acronym: EER (Engineering Education Research). A key player was the Journal of Engineering Education which had pivoted towards a research focus (Lohmann, 2005). An oft-cited paper from this period scoped out 'The Research Agenda for the New Discipline of Engineering Education' (Adams et al., 2006). Writing very much from a US perspective, the authors state:

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> Research in engineering education must become the engine that drives change to improve the technical fluency of students and teachers, increase interest in engineering and awareness of the social impact of the engineering profession, increase diversity in the engineering student body, and increase the United States' contribution to the global engineering workforce (p. 259).

It is evident that the 'research agenda' put forward was framed mostly around change and offered an argument (especially to funders) that it carried the potential for increasing both the number and diversity of enrolments in engineering. This, it was argued, would then have a knock-on effect, impacting on the workforce and global competitiveness of engineering in the USA. Some later work has interrogated the methodological focus on 'rigour' in this article (Riley, 2017), but the proposed aims for the research remained unquestioned.

Five years later, the Journal of Engineering Education carried another influential paper which aimed to offer an international perspective on the emerging field of EER (Borrego & Bernhard, 2011). These authors outlined what they saw as five motivations for EER (based on a selection of published work from different national contexts):

1. Increasing diversity (of engineering professionals), including participation of those historically underrepresented in the profession;
2. Improving the public image and understanding of engineering, which is believed to be key to attracting a broader range of students;
3. Preparing students to solve complex problems, which involves change to the way in which engineering students are educated, in order to produce graduates with the skills and attributes needed for a changing workplace;
4. Meeting the challenges of globalisation, which relates not only to the skills referenced above, but also to advancing global systems of accreditation of engineering qualifications;
5. A deeper understanding of learning to improve learning: improving EER methodology and dissemination of findings to avoid 'reinventing the wheel' by trial and error.

This list of motivations offers more detail on the ways in which EER researchers argue that their research will contribute to change, particularly in relation to who are recruited to engineering, and how they are educated. Here the authors show that the overall motivations for the research have global similarities, even though some of the details might change – most

notably in relation to which populations are the focus for increasing diversity. Overall, it can be seen that these arguments for change are based on a sense of a rapidly-changing world, the period after the end of the Cold War having seen dramatic geopolitical and economic realignments which exacerbated concerns about national competitiveness in many parts of the world, and rapid advancements in technology which put engineering education prominently on national agendas (see Lucena, 2006).

Klassen and Case (2022) offer a fuller survey of this literature from the early 2000s that sought to legitimate EER, outlining aims, purposes and scope. Drawing on Basil Bernstein's notion of a 'region', they identify productive tension between a view on EER that looks inwards to other social science disciplines for research questions, and a view that looks outwards to the world of the classroom and the profession itself for relevant problems to solve.

A further useful framing for thinking about research fields and their orientations is represented in Pasteur's Quadrant (Stokes, 1997) (Figure 1). This classifies fields on twin axes: firstly, whether they aim towards furthering understanding, and secondly, whether they aim to produce findings of use i.e., whether they can be used to solve immediate problems in the world.

Research is inspired by:

		Considerations of use?	
		No	Yes
Quest for fundamental understanding	Yes	Pure basic research (Bohr)	Use-inspired basic research (Pasteur)
	No		Pure applied research (Edison)

Figure 1: *Pasteur's Quadrant (adapted from Stokes (1997, p. 73)*

The value of this quadrant is that it identifies not only fields that are purely in the domain of basic research (as exemplified by the physics research of Niels Bohr) or fields that are purely applied (as in the work of Thomas Edison). They also characterise fields that hold both of these aims with the term 'use-inspired basic research', as exemplified in the work of Louis Pasteur.

Likewise, Engineering Education Research, in its focus on building rigorous methodologies and a scholarly knowledge base, as well as its orientation towards what it sees as urgent needs for change, can be seen to fit this description.

Thus, we argue that EER aimed at building a fundamental *understanding* of what is happening in a given educational environment is important, but additionally, in a changing world, educational environments must adapt to be fit for purpose. The ideal is to effect change based on a solid understanding of the current situation in a trajectory that aligns well with our perception of the changing needs of our world. EER thus fits comfortably within the framing of 'use-inspired basic research' in Pasteur's Quadrant.

This article thus embraces these twin aims for the field but argues that if our research field is to be framed at least partly in pursuit of change, we need to make sure we have in hand an understanding of how we might think about change in (engineering) education. This is to say that having a robust and rigorous description of a system is necessary but insufficient of itself to effect change. If we are to have a view on how change happens in education, then we also need a perspective on causal mechanisms.

In this article we begin by exploring what can be achieved through educational change. We start by pointing to the limited efficacy of achieving social change through education alone, in order to illustrate the complexity of causality in social systems. We then turn to the work of Roy Bhaskar to illuminate ways of thinking about causal mechanisms. Critical realism seeks to afford transformational changes but refuses any reductionist notion of causality.

Education and change

Arguments for change in education form a central part of many contemporary social debates, whether in relation to compulsory or post-compulsory levels. In her history of the development of education research in the USA, Ellen Lagemann offers the view that Americans have 'evangelical expectations for education' (p. xi). She observes that for a society which is invested in a fundamental belief in the possibility of individual self-improvement, achieving social change through education might be considered more palatable than other means. But a focus on educational change as the key for social reform is not limited to societies which are stereotypically considered to value individualism, and here we might turn to South Africa to

note Nelson Mandela's famous and much-quoted aphorism from 1990: 'Education is the most powerful weapon which you can use to change the world' (Mandela, 1990).

For an empirical basis on which to base our thinking about education and change, in this section we turn to an overview of key findings from the field of the sociology of education that offer a high-level view of the history of educational reform movements and educational change, spanning both compulsory schooling and post-secondary education.

Setting out on an historical overview of education in the USA, Rury, in his book, Education and Social Change (2012), notes the problems of a tendency to over-expect on what education can deliver: 'Is relying on educational institutions to address larger social problems a strategy ultimately doomed to failure or disappointment? The answer to this question is a persistent puzzle in American history, for people in this country have placed uncommon faith in the power of education to improve society' (p. 1).

Surveying the early 20th century, he notes how the dramatic expansion of secondary schooling certainly had a significant impact on the economy, by providing workers with higher levels of education. But at the same time, this was the era of progressives like Dewey, and their vision that education would foster a more democratic and humane sense of community was arguably not achieved, as the American high school developed as an institution that certainly fostered youth culture but incorporated different sub communities depending on social class. In the post-war period, issues of inequality and social justice rose to the fore, especially during the civil rights era, and many felt that education reform would help achieve resolve these issues. In fact, this was the period where significant federal funds started flowing to schooling, to attempt to alleviate social inequalities. Despite these unprecedented levels of funding, no significant progress was made in terms of relative school outcomes. Studies started to show the troubling finding that family background was a greater causal determinant of school outcomes than anything that happened in the school, at least at a macro level (see, for example, Coleman 1994).

This is education's 'inconvenient truth' and why social policy focused solely on education as a change agent is doomed to fail. For a whole range of reasons, individual students respond differently to education environments, and even when these environments are improved, it is hard to avoid differential outcomes. Advancing social equality is probably more effectively done through measures in the areas of labour and tax reform, child welfare, public housing etc.

The sociologist Basil Bernstein (1972) famously (and controversially) wrote that 'education cannot compensate for society' (p. 159).

Similar overall findings are seen in the context of the UK, surveyed in the book Education and Society, written by the sociologist Rob Moore (2004). Moore commences his investigation with the observation that in education, 'the kinds of things expected to make differences often do not' (p. 2). To understand those changes that we *have* seen in education and education outcomes in the post-war period, Moore argues we cannot find explanations only within education; we need to locate these in an understanding of broader dramatic changes in society over this period: in the nature of work, in family structures, in the role of women, and around multiculturalism.

Looking at social class, over this period, despite its being a major focus for reform and the impetus for significant interventions, especially in schooling, there has been no change in relative outcomes, although there has been an upward change in absolute outcomes. Conversely, this period has seen what is often termed a 'gender revolution' in terms of women's participation and outcomes in education – but here the reform efforts were at best fragmentary. Moore argues that these changes are certainly more due to changes in broader society than anything else. In terms of ethnicity, it is entirely dependent on which group one is talking about; some have seen huge relative changes in educational participation and outcomes, and others have not. Overall, Moore reflects that the degree of social mobility in modern societies is so great as to negate the Marxist reproduction thesis, but also not enough to support the liberal open meritocratic ideal.

In terms of national comparisons, Moore raises further questions about causality: 'It might be that richer societies have more developed education systems because they are richer, rather than their being richer because they have more developed education systems' (p. 36).

Contemplating this brief survey of key work in the sociology of education, it is clear that simplistic views on the causal relationship between education and society, and especially between educational change and social change cannot be sustained. What makes this challenging is that this goes against some deeply-ingrained views in contemporary society. As already mentioned, education tends to take a central place in our debates on social change. Moore notes that a reason why education is such a primary focus for reform is that 'it is amenable to change in a way, say, that structure of the labour market, family relations is not'

(p. 6). Education thus gets treated as 'the principle means of creating a more equal society' (p. 7).

Drawing further on Lagemann's (2000) work, cited in the introduction, she notes a surprising tension in society between, on the one hand, 'evangelical' expectations for what education can achieve, and on the other hand 'popular disdain for education and educationists' (p. xi). She argues that '[t]his tension has fuelled an impulse to extend education to more and more people and to rely on it for an ever-increasing range and variety of social purposes, while also encouraging a reluctance to bear the costs of supporting education at truly adequate levels' (p. 3). Importantly, she notes how education is located in 'larger constellations of social values and views that have often found their clearest manifestations in debates about education….' (p. xiii).

Returning to Moore, he argues that these commonplace justifications for why we embark on education research might help us to obtain external support and funding for our endeavours, but they might also seriously limit our thinking on the true capacity of education to stimulate individual change. Here he makes a subtle but important argument:

> … if the *instrumental* capacity of the education system to realize certain kinds of economic and social policy objectives is weaker than has often been thought, then there is less justification for restricting the flexibility of schools in realizing intrinsically *educational* objectives ....The final implications of these sociological accounts might well be that the best reasons for doing things in education are educational reasons, and that educators are best employed pursuing these intrinsic aims rather than being harnessed to external objectives (p. 118).

In concluding this section, we note that simplistic arguments about the causal relations between educational research, educational reform and societal change cannot be sustained. Education systems do change, often quite substantially (contrary to the argument that they don't) but they don't always change in the directions that the reformers might have intended. In general, educational change seems to be caused more by changes in the external social and economic environment than the prescriptions of those within the system, such as teachers and scholars with a reform mindset. Moore argues that instead of abandoning our work, we should be prompted to focus our efforts more directly on the educational purposes of education rather than its external impacts. In other words, we might narrow our focus from big arguments about reforming engineering education to effect social change, to focusing on educational reform to shape engineering graduates to take on the challenges of the world as we know it. Nonetheless,

the narrowing of our focus might still not be sufficient to ensure that we are able to reform education in the ways that we intend. We need to take causality into account, specifically how causal mechanisms might work in the social world.

Effecting desirable change in education – a turn to critical realism?

To propose a way forward in thinking about causal mechanisms in engineering education, we draw on the critical realist philosophy of Roy Bhaskar (1978; 2008; 2009). In his early work, Bhaskar was driven by curiosity about the nature of the physical world. For Bhaskar, there is an ontological reality which we attempt to explain through epistemology. But our epistemology is always subject to improvement through judgemental rationality in the light of new empirical information. In A Realist Theory of Science, he proposes that there is a three- tiered nested structure of the physical world. The largest sphere is the 'real', which encompasses all that exists and all that possibly could exist. This includes the causal mechanisms that bring things into being. The middle sphere is the 'actual', and is the world that is in existence. The smallest sphere is the 'empirical', which is that which is observable. This means that which can be empirically observed is always a subset of that which actually happens which itself is a subset of that which can possibly happen. This is because not all possible causal mechanisms are always enacted.

There are three important phases in the scientific endeavour. Firstly, to describe accurately that which is empirically observed. Secondly, to postulate the possible causal mechanisms which give rise to those observations. Thirdly, to evaluate the reliability of that proposed explanation (Blackie, 2022b). The last of these is greatly enhanced through conversation and interaction with others who are trying to investigate the same causal mechanisms (Blackie, 2022a).

In a later development of his thinking, now called dialectical critical realism, Bhaskar turned his attention to social systems. A recently published interview with Bhaskar (2017) offers a compelling starting point for why this is a productive orientation for engineering education researchers to draw on. Here, Bhaskar offers three key characteristics of critical realism. Firstly, it is a *serious* endeavour; it cares about the world and seeks for societal betterment. Secondly, it is committed to *immanent critique* i.e., the criticism comes from the inside, from the community of researchers. Thirdly, it is directed towards *enhanced reflexivity and transformative practice*. These principles resonate well with the field of engineering

education research, and there is the promise that this interrogation might allow for an enhanced characterization of research priorities and what this means for the use of theory and method towards framing research designs.

Some policymakers from the 1990s onwards have been in thrall to the notion of 'evidence-based research' which has been so influential in fields like medicine (Parkhurst, 2017). However, education scholars have raised a number of difficulties with this approach. There is a significant field of education research that works quantitatively to measure the impact of educational interventions. Here the overall finding by John Hattie and colleagues after doing 800 meta-analyses of some 50 000 research studies on teaching and learning is noteworthy:

> The most important discovery from the research was that almost any intervention can claim to 'work'. Almost every intervention had an effect size above zero which simply means that the intervention had some positive effect on achievement. However, if every intervention has some effect on achievement, then all we need to do is implement more of what we already do – so all we need is more money, more resources, more teachers, and all of our problems will be solved. However, this will not solve the problems in education. Instead, we need to be more discriminating (Inside Visible Learning, n.d.).

In a key overview article considering the potential for evidence-based practice in education, Biesta (2007) points to two specific issues. Firstly, much of the thinking around evidence-based practice tends to focus on questions of efficiency or so-called effectiveness, not taking into account that what is a desirable outcome is not necessarily a simple matter, easily agreed on. But a second key issue that we take up further here relates to how causal mechanisms might work in education. Teachers teach and learners learn but the causal link is not straightforwardly linear (Case, 2015). In Bhaskar's terms a rigorous empirical observation of a particular situation does not constitute knowledge of the causal mechanism, but it is a necessary first step upon which to build understanding of these mechanisms.

For Bhaskar a simplistic causal connection is untenable. The world is more complex. There are multiple strata of reality operating in any educational setting. And each stratum has its own set of causal mechanisms. According to Bhaskar (2008), if we are to effect change in any system, we must consider four different planes: the physical environment; social interaction between people; the social structure in operation; and the particularity of people. The causal mechanisms in all four planes are not likely to be equally influential in a particular research context but we cannot presume the absence of a complex operational mechanism which may

significantly influence the effect of any change. Indeed, Bhaskar puts it slightly more negatively, stating that transformation is unlikely unless we consider all four planes.

Bhaskar gives us two insights which indicate why many interventions can be shown to 'work' as per the research of John Hattie referred to above, but in fact might fail to be transferable to other contexts:

1. We conduct education research in a manner that focuses on effect without interrogating causal mechanisms in play. On a trial-and-error basis, elements are added or removed, and the outcome improves or doesn't to some desirable measure. We are seeking an effect, not an explanatory concept. As such, the methodology is more akin to alchemy than science: if we just get the mix right, we can attain the desirable outcome. But here we would be working in the absence of understanding that the 'mix' includes the social context, the preparedness of students, resilience to change, personal power of the reformer etc. Transferring the 'recipe' to another context comes neither with a guarantee of the same effect, nor any clear sense of what might need to be adapted to be effective. Essentially, the error here is taking the change in empirical data to be evidence for enacting a different causal mechanism when we have no foundation for making such a claim.

2. Our paradigm for exploring and improving phenomena might be influenced by our training and experience in engineering. Thus, the context is described in many studies, but little consideration is given to the causal mechanisms which may be operational in that particular context. Most papers focus simply on one of the four planes of social being that Bhaskar has identified. The fact is that any educational endeavour is necessarily an open system. This system is further confounded by the double hermeneutic (Price, 2019). Not only are we as researchers interpreting the system through a particular theoretical lens, but the students in our study are responding based on their own independent interpretation of the intervention. This is true whether the study is of the 'do this, then student marks get better' kind or leverages the more nuanced ideas of social structure such as structure and agency (Archer, 2000) or power (Bourdieu, 2004).

This is not to suggest that there is no value in careful descriptive research. The curious educator who is willing to try new interventions and attempts to measure impact is absolutely necessary to the improvement of education. All great discoveries begin with that beautiful question 'I wonder…?'. However, Bhaskar's perspective shows us why our desire to transform education is simply not possible if this is all that we are doing. If we are to effect serious change, we must seek to develop conceptions of the causal mechanisms that might be in play.

As an analogy, lost in history is quite how the combination of charcoal with molten iron came about, which resulted in a far stronger material we now call steel. Metallurgy has long been an important part of human development. But far outstripping the trial-and-error approaches of alchemy were the advances in materials science that were possible, once a molecular understanding of matter came about with the advent of modern chemistry. We are thus arguing for a similar approach to engineering education research. It will surely take the efforts of many to construct a causal 'map' for educational reform. And it is not likely that we will be able to create a complete map, but the recognition that there is a multiplicity of causal forces in play will serve to moderate naïve claims of 'success' in EER.

Concluding comments

This article commenced by considering the arguments that tend to be made around the purposes of EER. It was shown that reference is often made to much needed changes in engineering education, whether in relation to recruitment, the forms of education, or global accreditation. Characterizing EER as "use-inspired basic research", we argued that such fields do need to think about how they conceptualize change in relation to the phenomena they study. We then moved to consider the evidence from the sociology of education about causal relationships in the domain of education. Here it is clear that while educational systems do change, such change is often not a direct result of educational reform efforts. In short it is society that often causes education systems to change, rather than the primary cause being in the stated direction. We then considered some of the critiques of evidence-based education research before moving to the critical realist philosophy of Roy Bhaskar for a more nuanced ontology that might inform education research directed towards characterising causal relationships.

Drawing now on a critical realist perspective on causal mechanisms, we move to consider what it might it look like to undertake engineering education research that works with these less simplistic notions of change. We note that this might involve more complex and ultimately

somewhat more modest arguments in relation to the purposes of EER. This involves rejecting any simple notions of development, as well as a clear rejection of a positivist orientation to research. For those trained in STEM this can involve a critique of our own socialization to engineering and its commitment to economic and social development through technological advancement.

Critical realism offers us the possibility to take cognisance of an interpretivist stance, a focus on *verstehen* – 'understanding people and ourselves' – but also to move beyond this to identify causal mechanisms. What is really going on in the education systems we research? What forms do they take and why? What is changing and what is not changing? What are the forces that promote change and what forces limit it?

Perhaps the call here is to take the time to consider what we are actually trying to achieve with any single EER project. There is merit in research which is essentially a rich description of particular situation. If this is sufficiently careful and well-communicated it will provide essential information for those who are more focused on investigating causal relationships. It is clear though, that without a broad understanding of the pressures and influences on a particular situation, even the most well-considered, evidence-based approach may completely fail to have the desired effect. Social systems are not constrainable in the way physical systems may be. Those of us who come from training in interrogating physical systems can underestimate the complexity at hand in the microcosm of an engineering course that looks to be in one person's control. Taking on board a critical realist orientation holds great potential for EER that can both advance in its ability to understand what is at play in a given context, and also to use this understanding of causal mechanisms to plan effectively for change.

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