Dilemmas in Framing Research Studies in Engineering Education

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Abstract

There has been considerable debate about the need for more empirical, evidence based studies of the impact of various interventions and practices in engineering education. A number of resources including workshops to guide engineering faculty in the conduct of such studies have emerged over recent years. This paper presents a critique of the evolution of engineering education research and its underlying assumptions in the context of the systemic reform currently underway in engineering education. This critique leads to an analysis of the ways in which our current understanding of engineering, engineering education and research in engineering education is shaped by the traditions and cultural characteristics of the profession and grounded, albeit implicitly, in a particular suite of epistemological assumptions. It is argued that the whole enterprise of engineering education needs to be radically reconceptualized. A pluralistic approach to framing scholarship in engineering education is then proposed based on the principles of demonstrable practicality, critical interdisciplinarity and holistic reflexivity. This new framework has implications for engaging and developing faculty in the context of new teaching and learning paradigms, for the evaluation of the scholarship of teaching and for the research-teaching nexus.

Introduction

During the 1990s there was a sustained global debate about reform in engineering education. The EC 2000 developed by ABET typify the shift towards a broader set of measurable outcomes that emerged from this process. Similar reforms have taken place in other countries. For instance in Australia, the report of the national Review of Engineering Education entitled *Changing the Culture*[1] lead to a change in the accreditation of Australian engineering programs based more on outcomes with a particular emphasis on the demonstration of broader graduate attributes. This change has challenged engineering colleges to investigate and evaluate valid and reliable means of assessing student learning and performance based on research. [2-5]

The question of quality in higher education, especially in undergraduate teaching is a growing political issue. The various stakeholders, including students, governments, industry and the wider community, are seeking greater assurance that they are receiving value (however that is measured) from their investment in higher education. This current "preoccupation with quality" [6] and its implication of higher education is a source of considerable debate and discontent. In countries including the UK, Australia, New Zealand and South Africa, national agencies have been established to monitor quality through a structured process of assessment of institutions.

Accreditation procedures like EC2000 and those of the Institution of Engineers, Australia align with this growing demand for transparent quality processes to be in place. International agreements for mutual recognition of engineering qualifications, such as the Washington Accord, further strengthen this through cross evaluation and comparison of accreditation processes between countries.

Both the reform in accreditation and the new focus on quality processes and outcomes by the various stakeholders, are powerful drivers for more fundamental research in engineering education. The two are interconnected and both embed the idea of the need to know what works and why and how practices can be continuously improved. While the obvious focus might be in measuring the implementation of new practices and systems, there is an underlying expectation that fundamental and applied research will guide these reforms. The NSF Strategic Plan in 1995 identified the integration of research and education as a core strategy and Fortenberry [7] foreshadowed new programs from the NSF to support educational research in Science, Mathematics, Engineering and Technology disciplines, ranging from fundamental research, to applied research and implementations. The proposed research agenda, while generic in its description, aligns with questions that are being raised as a by-product of the new accreditation processes and the socio-political quality agenda.

The dilemma facing engineering faculty wishing to evaluate some aspect of teaching or learning is how to frame the study. Should they work with colleagues in a School of Education or Teaching and Learning Development Unit and, if so, how do they find common ground? Are they trying to add to the literature on education or merely frame questions based on current theories or previous findings? What is an appropriate scope of study for the results to be significant? What questions can realistically be asked (in particular circumstances), as well as which is the most appropriate research methodology. How should a graduate student from engineering be prepared to undertake work in this field? There are also numerous ethical and organizational questions to consider.

This paper presents a new approach to addressing this dilemma. To set the context, it is helpful to explore recent trends in scholarship, innovation and research in engineering education.

Scholarship, Innovation and Research in Engineering Education

There has been a sustained discourse on matters concerning the practice of engineering education for at least a century, through the journals of the various professional engineering societies including a number of journals with education in the title. In the USA, this discourse has been punctuated by a series of reports and reviews commencing with oft overlooked Mann Report [8] from 1918 which makes one wander what has really changed. These periodic evaluations of engineering education are usually driven by external changes including the incorporation of alternative academic emphasis as faculty were hired out of other educational traditions, the engineering science revolution in the late 1950s that had a global impact on engineering education, and now the reforms focused on graduate attributes.

From the 1960s, research in engineering schools was largely about the study of engineering related phenomena or technology development grounded in a positivist, scientific approach based on the reductionist physical sciences research paradigm. Wankat and colleagues [9] suggest that in the USA, research in engineering education began to gain greater recognition, status and attract more faculty to the field in the wake of NSF funding from the Division of Undergraduate and the creation of the Engineering Education Coalitions. They also cite the ABET EC 2000 reforms as a significant development that supported the growth in scholarship of teaching and learning. In the UK and other Commonwealth countries that inherited the British model of university there has been a more diverse tradition that embraced engineering science research while retaining a vestige of earlier scholarship and innovative practice in engineering education notably in the fields of design and manufacturing. Various groups like the WDK Workshop (now the Design Society) fostered a tradition of scholarship in education around engineering design in Europe.

A number of issues have constrained scholarly activity, innovation and now research in engineering education. These include technological determinism, enthusiastic loan rangers, practice without theory, a lack of criticality and a baccalaureate focus. But there are some positive signs.

Technological Determinism

The work of engineers fuels technological determinism, so it is not surprising that much of the attention in innovation in engineering education from the 1950's until the present has been driven, if not determined, by available educational technology that could be applied. From the early use of visualisation aides, to audio-visual devices (film, audio cassettes, early video), from computer assisted instruction through to the use of the Internet, or from CDs to multi-media and mobile computing, it seems that it is the technology with "enormous potential" looking for an educational problem to satisfy. In the current context of the undergraduate reforms, information technologies are seen as being able to support the "a key enabler aiding institutions to effectively collect, analyse, report and apply the results [of changes] to the benefit of all constituents" [4] and that there is a need to explore much further how these technologies "can support the validity and effectiveness of comprehensive assessment programs in the university environment." [4]

Many technologies did not reach their expected potential, however there is always another ready to take its place. Technology has clearly made a significant contribution, but it is often oversold. It can be used creatively to simultaneously support student work <u>and</u> as a resource for student reflection or for an external researcher to better understand how they work and learn, taking into account the social nature of learning.[10] But even here the technology can be seductive for engineers or simply too sophisticated to be made widely available (beyond the technologically privileged). Ensuring that technology is a means rather than an end is a constant struggle in a technologically rich environment. It is also difficult for those who control the budgets to resist technology, if it seems to offer a potential cost saving.

Lone Enthusiasts

It has been observed[11] that innovation in teaching practice in higher education generally is often the province of enthusiastic individuals whom Taylor[12] describes as lone rangers. This pattern applies equally in engineering education. These enthusiasts sometime infect others and the idea spreads, mutates and grows. This diffusion is illustrated by Stice[13] in his personal recollections of thirty years of innovations in engineering education.

But equally many of the innovations don't diffuse and develop. Others are merely re-invented at another place and another time. Hannan and colleagues [11] found that the motivations for innovation by individual faculty were to improve student learning, to respond to changes in student intake, to address the requirements of external agencies or to cope with changes in curriculum or re-organisation. These innovators were inspired by amongst other things; previous experiences (usually elsewhere), a supportive environment (e.g an innovative department), staff development courses and conferences, strongly held beliefs. Only a few derived their inspiration from aspects of their research work.

The future of the sole researcher or the lone scholar in an engineering school is threatened by the rise and rise of the large, usually multi-disciplinary, research laboratory or institute and the strategically directed funding from research agencies and university administrators. Similarly, the move to guided initiatives in (engineering) education research in higher education involving (cross institutional) teams of people dealing with externally determined issues aimed at gaining the maximum impact for the research dollar is ominous for the future for the lone rangers. This economically rational, but it often loses the link to frontline teaching and learning needs.

Practice without Theory

The practice of teaching and learning in engineering schools has been notable for the almost compete absence of any underlying pedagogical model or theoretical framework. While the same might be true of teaching in many other disciplines at university, there is no compensating scholarly discourse around the philosophy of engineering as there is in say medicine, the sciences and mathematics. There have been some notable, but isolated, exceptions like Forman and Ferguson but these do not inform the thinking of the typical faculty member in engineering. It is paradoxical that a teaching community whose courses hinge on theories and models does not see the need, collectively, to develop and discuss theories about the activity central to their role as scholars. Most faculty have views, often strongly held, on the nature of teaching and learning, but these are seldom articulated or critically examined in a scholarly sense against what is published in the open literature.

The papers in the engineering education literature[14] make very limited use of the wider literature in higher education, beyond the handful of classic monographs such as Bloom, Perry, Schon and Kolb. Even this is a relatively recent phenomenon. One can reasonably speculate that most faculty in engineering schools are not even familiar with these types of writing much less underpin their teaching practice by them. The exception to this generalisation is the growing number of faculty who have been exposed to these through professional development programs and now Graduate Certificates in Eduction.

Engineering education has much to learn from and contribute to the wider, philosophical and empirical literature in higher education. The higher education community has recognised the distinct characteristics of different disciplines when it comes to university teaching and student learning.[15-17] It can be argued the whole concept of educational theory is problematic as it opens up more basic questions about what we understand by knowledge and learning and issues of social structure and power and so on.[18] But whichever way you approach it, there remains a rich discourse in pedagogy and associated areas that engineering educators, as a community, are currently only on the periphery of.

Uncritical Innovation

Faculty accept as a given that when embarking on a new research project or investigation or for that matter a new engineering project, you should find out what is already known about the area and become familiar with the relevant prior art. Echoing the point made earlier, it is therefore difficult to understand why these same faculty, when commencing their teaching or introducing new teaching methods or new instructional technology or innovation pay, scant regard to the published literature or take the time to critically examine the practices and experiences of others attempting similar things. As Elton[19] puts it, academic staff should "bring to their teaching activities the same critical, doubting and creative attitude which they bring habitually to their research activities".

Until relatively recently, most of the accounts of innovation and experimentation in teaching and learning in engineering education published in journals and presented at conferences were descriptive and largely lacking in critical analysis, much less independent evaluation or comparison. As Wankat and colleagues[9] observe, "engineering professors, like professors in every field, have always experimented with innovative instructional methods, but traditionally little was done to link the innovations to learning theories or to evaluate them beyond anecdotal reports of student satisfaction." There are signs that this is now changing.

Baccalaureate focus

The engineering education literature in general and the research literature in engineering education in particular, are focused predominately upon undergraduate programs conducted on campus and in classroom settings. While there has been more exposure to distance learning (including international programs), graduate education, and continuing professional development in recent years, teaching (and learning) is understood in more or less conventional, instructional environments for baccalaureate students. In Australia, there has been a marked change over recent years in student life brought about by a substantial increase in part-time work to meet the higher costs of their education. As a consequence, formal instruction is increasingly becoming a smaller proportion of the educational experience of students, with the Internet and other forms of remote, asynchronous, team-based and distance learning replacing the conventional laboratories and lectures. The expectations and approach of students in "generation X" are also quite different to those of faculty and there are signs of student disengagement taking place. These sorts of changes are profound, but seldom discussed explicitly in the engineering education literature.

Neither should it be overlooked that the baccalaureate qualification is but the first step in the professional formation of an engineer. The EC2000 have established a set of attributes upon completing this period of formal study, but these criteria were devised on the assumption that ongoing processes of professional development, and even lifelong learning, would follow. Professional formation as a coherent process is missing in large part from the engineering education and research literature.

Neuman[15] argues that academics in the "hard pure" and "hard applied" disciplines like physics and engineering think of postgraduate students on the context of their research work rather than as part of their teaching work. With the growing numbers of graduate students, the general higher education research literature has an increasing emphasis on the learning experience of postgraduates. Graduate schools are becoming more intentional about the professional development - the broad education - of graduate students. Some have suggested that there is a crisis in doctoral education[20] as it comes to terms with being more than simply a mechanism for reproduction for the academy. The wider adoption of the professional doctorate is another sign of fundamental change in the form and nature of advanced study in engineering and technology. These are topics that remain at the fringes of research and scholarship in the engineering education community.

Beyond Self-sufficiency

There is a growing recognition in the engineering education community that research methods from the social sciences have a crucial part to play in our research agenda. Both quantitative and qualitative methods are seen as essential in the effective assessment of the attainment of some of the skills specified in EC2000 (or comparable list of graduate attributes) including such methods as survey instruments, cases studies, interview methods, protocol analysis and content analysis. The application of such techniques to date in engineering education has often been undertaken by engineering faculty with little or no training or experience in their use, to evaluate student learning or instructional innovations. While this uptake recognises the need to move outside our disciplinary pantheon of research tools to access the most appropriate ones, it also illustrates the sort of intellectual chauvinism and cavalier self-sufficiency that engineers have a reputation for.

But beyond issues of disciplinary silos and chauvinism, it is simply poor practice as researchers to adopt (and sometimes adapt) methods from a quite different disciplinary tradition without first apprenticing in their tradition or at least developing a deep understanding of and appreciation for the philosophical debates and epistemological assumptions that surround them.

It is therefore encouraging to see a growing number of examples in the literature of engineers collaborating with education or social science researchers. At present these usually involve only a multi-disciplinary approach[3], i.e. one where each discipline brings their expertise to the study but there is no real cross-fertilisation. Over time it is hoped that more interdisciplinary studies will appear; that is investigations where researchers from quite different disciplines work together and develop sensibilities and rapport that enables them to straddle disciplines seamlessly. Such behaviour is built upon appropriate preparation, mutual support and training (formal or informal). But in order for a more inclusive and integrated approach to engineering research can emerge, the engineering education community must confront a number of issues that currently limit our ability to realise this potential.

In order to tackle these issues coherently, it is helpful to look deeper at the foundations of the profession and their influence on how we as engineers, approach the task of educating future engineers.

Characteristics, Culture and Epistemology shaping Engineering Education

Like any profession, engineering has certain defining characteristics, traditions that are nurtured by a rich heritage and a view of the world and its place in it. Some of these characteristics are consciously known by the profession while others are revealed to those with whom they interact. Holt[21] suggests that "day-to-day engineering work is energized by a unique belief system which forms an enduring and coherent engineering ethos". He goes on to argue that "the engineers' view of the world is at once formative, utilitarian and reductionist" and it follows that "good engineering practice comes from the productive synergy of these elements."

The typical engineer is reported by Beder[22] to be concerned with order and certainty and therefore to be averse to ambiguity, to have a rather narrow range of interests, to be not given to introspection and not much interested in people. Yet engineers are being challenged through the changing nature of engineering work to deal with ambiguous and changing circumstances and in a complex and emergent social and environmental context.

The dispositions and institutions that maintain engineering practices include positivist approaches to knowledge and sets of values such as a high degree of individual competitiveness, the valuing of long work hours for their own sake and the sacrifice of other aspects of self and life to the professional identity[23]. These are all traits that militate against the development of the professional self through reflection. These characteristics have profound implication for engineering education and research into its practice.

The ability to visualise and "see" things in the mind's eye[24] before they exist in the physical world, is a defining characteristic of traditional engineers. It remains central to the culture and art of engineering, challenged but not discarded in the scientification of engineering. With the advent of CAD and the shift in engineering to less tangible products (as in software engineering), this capability is no less important (if differently conceived) for interpreting and understanding molecular level structures in advanced nano-technology or interpreting visualisations of complex data sets as well as in the more traditional engineering areas. Engineers prefer to communicate through simple graphical means, rather than having to follow tightly argued narrative. A pertinent example of this is the paper on Perry's model of intellectual development by Culver and Hockos[25] in 1982.

While Perry's monograph had been on the shelves for nearly 20 years, it had not impacted much to that point on the engineering education community. They made Perry's work much more accessible to an engineering audience through their creation of a simple time line diagram that capture the essence of his findings. Colleagues in the social sciences and humanities will be aghast at the reduction of such a rich narrative into a conceptual model in the form of a diagram, but this diagram provided a visual hook which encourage more engineering educators to become aware of the work and the motivation to go to the original (even though some were surprised when they found it had no diagrams or figures).

Based on a review of papers in the Journal of Engineering Education from 1993-1997, Fortenberry[7] observes "a certain insularity is observable within engineering colleges as reflected in the lack of attention given to systemic reform and the complete lack of explicit adaptation of innovations from other disciplines" Granted there are signs of this insularity breaking down, it remains a strong culture of rugged individualism in academe - perhaps an essential characteristic of such an environment. In engineering, this often manifests as a particular form of intellectual arrogance that not lonely devalues other intellectual traditions and spurns contrary ways of viewing the world, but also presents a barrier to the sharing of knowledge and practice within it ranks. It has been argued that the profession must undergo a huge cultural change in its educational fundamentals, if it is to diversify from its allegiance to an instrumental problem-solving approach and embrace a pluralism that accepts as legitimate other ways of ordering our world.[26]

Graduate students in engineering do not get exposed to the philosophical assumptions on which their research methods are based, to anything like the extent that happens with social scientists. Few undertake any formal instruction in research methods. If they do, it is unlikely that other than the "scientific" methods - as a positivist way of understanding the world - will be considered. Exposure to alternative ways of knowing and to competing ideas about knowledge in a pluralist society should be part of their intellectual development - as per Perry. While in earlier times this may not have been such an issue, it has real consequences for the profession as it attempts to engage with a more complex world. Moreover it limits the ability of new faculty, lacking this grounding in diverse modes of inquiry, to engage with people outside the discipline in scholarship and research in engineering education.

In order to move forward, we must first take a step back and critically examine the epistemological foundations on which engineering education research is based and develop a more exclusive base from which to operate. It seems evident that for engineering to remain truly relevant to the issues of import for the society it desires to serve, then it must construct a pluralistic identity that embraces more than one way of knowing and acting in the world. While the pragmatic practice of engineering in industry is beginning to confront some of these issues through environmental and societal dimensions of technology (e.g. the triple bottom line), academe, through scholarly endeavours, has a vital role to play in bring about a new engineering.

A Pluralist Framework for Scholarship in Engineering Education

If we are to encourage more faculty to engage in empirical research in engineering education and thus raise its profile as a legitimate field of research in engineering schools then we have to address the issues raised thus far. It seems clear that a pluralist framework is required which locates scholarship within engineering education opens it to other perspectives in addition to the problem-solving paradigm.

Scholarship is used here in the Boyerian sense of the scholarship of discovery, the scholarship of teaching, the scholarship of practice and the scholarship of integration. These are taken to be an interrelated and interdependent suite of activities; it eliminates the need to evoke the artificial research-teaching divide. The publication of *Scholarship Reconsidered*[27] stimulated widespread discussion in the higher education research community and in disciplinary groups including engineering. Although the primacy of research (discovery) in the academic value system remains, teaching and other aspects of scholarship have received more attention. Much has been written in an attempt to clarify the terms and to explore their implications.

For example, Anderson[28] articulates three quintessential scholarly attributes thus; critical reflectivity as a sensibility (a state of mind), scrutiny of peers as a *modus operandi* and inquiry, as a motivation. Healey[29] argues that the scholarship of teaching involves engagement with research into teaching and learning, critical reflection of practice, and communication and dissemination about practice to one's discipline. Based on a review of the literature and a Dehphi study of a panel of "experts" in higher education teaching and learning, Kreber[30] concludes that while progress has been made in the past decade in taking the scholarship of teaching from what was an "amorphous and elusive term", greater focus is required if it is to gain equal recognition with "research", and this may best be accomplished by disciplinary networks.

In proposing a framework for approaching scholarship (in all its forms) in engineering education, the challenge is how to make it universal and useful; simple yet sufficient. Striking this balance is not easy. This paper errs on the side of simplicity and proposes a framework constructed from three guiding principles as follows;

1. Demonstrable Practicality
2. Critical Interdisciplinarity
3. Holistic Reflexivity

These three principles provide respectively; (i) an intrinsic motivation for all the stakeholders (including students, faculty and administrators), (ii) a contrary view to challenge tacit assumptions in engineering and engineering education and (iii) encouragement to adopt a critical, aesthetic and ethical orientation to the task.

The framework is not, as might have been expected, a flow chart or decision matrix to guide the choice of the most appropriate research method or a detailed instrument to assess the scholarship of teaching. Guides of this type already exist and more are appearing all the time. Rather the framework proposed here aims to complement these other form of guidance by locating them in more philosophical perspective. Each of these principles is discussed in turn.

Demonstrable Practicality

This foundation principle is fundamental if the scholarship of teaching and associated innovation and research is to gain credibility and be more widely accepted. It implies that any study should be based on an authentic educational task and, if successful, should achieve results that impact significantly on learning or teaching practice. It is about enhancing educational outcomes, for all the participants, in a fashion that is effective and efficient. This should not be interpreted as pragmatic utilitarianism but rather as ensuring that substantive issues be tackled, building on what is already known and avoiding wasteful studies that are inappropriate or have little chance of success (however that is defined).

This principle is implicit in a number of discussions on the evaluation of scholarship of teaching. For instance, Felder[31] includes the “effectiveness” of teaching and the “effectiveness” of educational research and development as two of the three issues to be evaluated. How this is measured is not a straightforward task however.

Another, more subtle, dimension to “demonstrable practicality” is that it seeks to know if the teaching activity or innovation actively develops the student’s ability to practice engineering in a rapidly changing and emergent future. In this sense, practicality is about developing attributes in engineering graduates that will empower their professional competence over both the short and longer terms. One of the key enablers is the fostering of deep and active, rather than shallow, learning approaches and generating learning-how-to-learn strategies. It is generally accepted that surface learning is driven by an overloaded curriculum and the nature of assessment. Ditcher[32] argues that problem-based learning provides the most appropriate learning context to encourage the development of "quality" learning and other desirable attributes including flexibility and the capability for lifelong learning that are expected to the contemporary engineer. This does not imply that all courses or whole programs must adopt a formal PBL structure. Indeed she suggests that a practical approach is to introduce problem-based work into existing courses, reduce the workload and focus assessment on testing for understanding.

In a similar vein, Holt[33] conjectures that the "growing move towards practice-based programs is a heuristic response to the perceived failure of content-based pedagogy". He is not advocating a return to the past but rather positing a new conceptualisation of professional engineering practice as incorporating four separate but contextually related elements: governance, enquiry, management and design. These four practice elements are shaped and instructed, in turn, by a set of principles based on four underpinning disciplines. The point here is that, practicality and how we demonstrate it, is not just a pragmatic matter of measuring outcomes and their impact. It also demands the development of a theoretical framework for understanding fundamentally what is happening; or to use the overworked Kurt Lewin quote, "There is nothing so practical as a good theory".

Critical Interdisciplinarity

Critical interdisciplinarity involves bringing the perspective of at least one discipline, other than engineering (or similarly positivist tradition), into critical juxtaposition with that the engineering faculty member conducting the study. This might be from education, the social or behavioural sciences or humanities. The interdisciplinary dimension implies that there is a substantial interaction between the different disciplinary perspectives and a level of interchange that causes understanding, assumptions, and core values to be challenged and sometimes shifted. It is much more than just hiring in some expertise from outside of engineering to assist in formulating an educational study. It demands commitment and a willingness to put firmly held, often precious, views and assumptions on the line. Above all it takes time and necessitates the development of high levels of trust, founded on mutual respect and professional humility.

In the context of a professional development course on teaching for university faculty from diverse disciplines, Rowland[18] contrasts three different approaches to running such a course. The first approach is to tackle the practical task of teaching, with a focus on developing teaching techniques. This "technical" approach is not concerned with theoretical or disciplinary perspectives or such problematic issues as the nature of knowledge or "what is learning? The second approach also sets aside any disciplinary frameworks of assumptions and approaches the course as an educational task rather than a technical or practical one. In this case, participants would be introduced to a body of educational theory.

The third approach is to value the disciplinary understandings that each participant brings and engage these different disciplinary perspectives and other perspectives in a critical fashion. This approach is critical interdisciplinary as it is critical at the point of exchange not within the individual discipline understandings. Rowland argues that having to deal with the inevitable contradictions and incongruity that emerge in inter-disciplinary discourse due to differences in the values and underlying assumptions of each, forms an excellent basis of developing a critical approach to teaching. It can also be argued that this is the essence of higher education - both for the students and the teacher.

Holistic Reflexivity

Jolly and Radcliffe[33] introduced the concept reflexivity as an essential part of a students' (life-long) education. Reflexivity is understood to be an ongoing process of reflection before, after and during action, revolving around the reflecting self. A distinction is drawn between reflection on engineering problems as phenomena divorced from the practitioner, and reflexivity as reflection on personal experience of engineering practice. This changes fundamentally the relationship between engineer and engineering. Reflexivity is the application of the fruits of reflection during action, and a higher order skill. It has long been a part of anthropological analyses, since the anthropologist needs to be constantly taking account of how their own cultural presuppositions inform their perception and understanding of other people's cultures.

In the context of teaching in higher education, Bleakley[34] critically examines Schon's notion of "reflective practice", arguing that there is a danger of it becoming "a catch-all for an ill-defined process". He explores the concept against four epistemologies that inform it; technical rationality, humanistic emancipatory, post modern deconstructive and radical phenomenological. Based on this he proposes the idea of "holistic reflexivity" which combines reflection-as-action with aesthetic co-intentionality and ethical reflexivity (or ecological co-intentionality). This is a difficult idea to convey in a few lines. A sense can be gained from his concluding remarks as follows; "Holistic reflexivity is an inclusive ecological or caring act of reflection as well as an appreciative gesture, with an explicit concern for 'otherness' and difference'.

Bleakley goes on to argue that holistic reflection should not be viewed "hierarchically as the 'peak' of a pyramid of reflective practices, nor teleologically as the eng point of a development process; nor morally as the best form of reflection. Rather, it can be viewed aesthetically, as a more complex, demanding, satisfying, and problematised form of reflexivity, where practice is conceived as artistry." Perhaps paradoxically, the challenge of having practicing engineers, engineering educators and engineering students understand the concept of holistic reflexivity may be much greater than that of them embracing it.

The potential for a profound rethinking of the way we "educate" practitioners through embracing a more reflexive approach can be seen in a comparable profession, medicine. Cribb and Bigold[35] advocate a shift in emphasis in medical education research, one that fosters a more interpretive and reflexive research paradigm. They point to the "hidden curriculum" in medial schools and to the tensions between the "objectifying" and the "humanising" currents in medical education. Similar tensions exist in engineering education, and indeed within contemporary engineering practice, as the profession confronts the changing expectations of it by the society. We can learn from the experience of medical education. The dangers inherent in introducing reflexive learning into professional formation and educational research in medicine and the willingness of the profession to embrace these new discourses have echoes in engineering education.

Going Forward

The pluralist framework presented here steps outside the pragmatic concerns of the engineering education community as we struggle, both individually and collectively, with pressing matters such as implementing EC2000 and fostering scholarship in teaching. The motivation was to view the issues from a more epistemological perspective, but one that will give rise to practical actions.

It is grounded in collective understandings from both engineering education and other intellectual traditions but needs to be further developed and tested. This will involve articulating the three central principles in terms of concrete examples.

The first step in this process is to offer the framework for comment and critique in the engineering education community. A series of case studies that illustrate its application will then be conducted. It is anticipated that the pluralist framework will contribute to the debate on the research-teaching nexus and shed light on the underlying issues in engaging and developing faculty in the context of new teaching and learning paradigms and for the evaluation of the scholarship of teaching. The framework is not limited to scholarship (including research) in engineering education but has potential application in disciplinary "research" (or more broadly, disciplinary scholarship in the Boyerian sense). At the risk of overstatement, faculty who do conventional research in engineering schools, limit themselves (collectively) to a quite narrow interpretation of what is engineering, focusing mainly on phenomena and technology and very little on the human process issues and the socio-technical act of engineering. By broadening the research questions we ask, the approaches we take and the results we look for, engineering schools will be more open, inclusive and diverse.

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