More by Luck than Good judgement: Moral Purpose in Engineering Education Policy Making for Change

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Abstract— **Since the end of the Second World War there has been a considerable growth in knowledge in what engineering education is about. This has been accompanied by a number of reports, particularly in the US, that to some extent are repetitive but in the language of the period. These reports were to a large extent based on informed opinion. These beliefs are deeply entrenched in Western Psyche and encompass beliefs about what students should learn, how they learn and how they should be taught. These views are obtained early being formed by the long experience of elementary, post-elementary and higher education and are often difficult to shift without a substantial *chocs des opinions*. Policy making is often made on the basis of opinion that has been informed by experience that makes itself into a self-fulfilling hypothesis that shuts out anything that is likely to create a dissonance. One consequence has been a growth of a gap between those who practice in classrooms and those who do educational research. In no other area of inquiry is the vast body of knowledge that is available on the theory and practice of education, theory taken in the broadest meaning of the term, ignored by those who make policy and practice in the classroom. It is contended here that that is morally irresponsible, and the fact that policy makers and practitioners do not have personal philosophies and theories of learning based on that world of knowledge is one of the causes of friction between these two groups. Decisions that work do so more by good luck, than good judgement. All should have received substantial training on which to build their advice, or consult with those undertaking research, and more particularly indicate research they think should be done.**

A not infrequent complaint is that teachers do not adapt to this or that learning strategy or use this or that particular tool (e.g. concept inventory). At the 2015 ASEE annual conference the representative of ABET lamented that academics had not used the assessment system to innovate. It is contended that innovation is unlikely in the absence of substantial prior knowledge that can enable an innovation to be progressed. It is similarly contended that the friction caused by the ABET proposals cannot be resolved without attention to knowledge that exists in the area of accreditation and assessment. The purpose of this paper is to review some of that research and scholarship as it relates to the proposition that university courses should produce graduates who are able to take up positions in industry without further training.

Keywords—Assessment, Competency, Industry, Moral intent, Policy, Training, Research.

I. INTRODUCTION

Since the Second World War there has been a considerable growth in knowledge in what engineering education is about which changes the moral responsibilities that educators have to their students and their profession. This has been accompanied by a number of reports, particularly in the US, that to some extent are repetitive although presented in the language of the period in which they were written For example the Grinter Report for ASEE in 1955 [1] and the Engineer 2020 for the National Academy of Engineering in 2004[2]. In the UK the results of Hutton and Gerstl's 1965 survey of graduate mechanical engineers produced a curriculum structure that was very similar to that suggested by Grinter [3]. These reports and others before them (e.g. the 1918 Mann Report [4]) are largely based on informed opinion rather than any systematic research although the Sheppard Report on engineering education of 2009 for the Carnegie Foundation for the Advancement of Teaching is an exception to that rule [5]. Sheppard and her colleagues wrote that (p208) "it is not clear to what extent engineering faculty are taking advantage of the field's increased understanding of engineering work and student learning to inform their teaching practices." They do not conclude that unlike school teachers whom the public expect to be trained, university teachers should be trained. For the most part university teachers are not required to receive training and what constitutes effective teaching is something constructed through osmosis from the

education they themselves received. But training is not necessarily a panacea as the experience of the in-company training of engineers and managers [6] and the training of teachers shows [7] [8]. Once in practice trainees adapt to the culture in which they find themselves. More often than not that culture, informed as it is by regulatory authorities is likely to be inimical to change. Borrego [9] has argued that if assessment is to be taken seriously a culture has to be created if that goal is to be met. Similarly if the gap between theory and practice is to be changed a culture has to be created that supports attitudinal change [10].

The issue here is, "*should* they be trained?" This may be answered quite simply by ruling that if there is a coherent body of knowledge that bears on the conduct of a particular occupation those persons engaged in that occupation have an obligation to be familiar with that knowledge and to have tested it in their practice with reasonable objectivity, the actions they take being on the basis of reason. This demands that they should have defensible philosophies of education and learning.

The question is, "whether or not there is a body of knowledge to which practitioners can refer and develop those philosophies?" Two solutions to this question have been offered. The first in 1995 asked the question "whether or not there is an equivalent body of knowledge to that provided in a traditional course for training post-primary teachers in Ireland?" This approach was taken because such a course delineates the areas of knowledge that contribute to the discipline of "Education." (i.e, Philosophy, Psychology, Sociology and History of Education together with Assessment and Evaluation and the Practice of Teaching a particular subject). A count and categorization of papers within these domains in the literature of engineering education showed that there was a body of knowledge in the engineering literature that would support the development of a training programme for engineering educators [11]. Now there is a vast body of knowledge that constitutes "Engineering Education" [12]. The second approach which is specifically related to the United States plots the chronological development of engineering education research in the US. It shows that it is an established field of scientific enquiry that supports the body of knowledge that is "engineering education" [13].

Irrespective of the argument from obligation there is another argument that stems from the need to respond to educational, social and technological change. A not infrequent complaint is that teachers do not adapt to this or that learning strategy or use this or that particular tool (e.g. concept inventory). It is contended that change or innovation are unlikely in the absence of substantial prior knowledge (training) that can enable change or innovation to be progressed. At the 2015 ASEE annual conference the representative of ABET lamented that academics had not used the assessment system to innovate which is not surprising given the lack of knowledge in the system. Without that knowledge it will be difficult to resolve the friction caused by the recent ABET proposals without attention to the body of knowledge that exists in the area of assessment [14]. The purpose of the remainder of this paper is to review some of the research and development in the area of assessment particularly as it relates to the proposition that university courses should produce graduates who are able to take up positions in industry without further training. It is set within the context of the moral intent of assessment.

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II. TEACHING AND THE MORAL INTENT OF ASSESSMENT

If it may be expected that every teacher should have a defensible theory of education that embraces learning as well as its aims then it follows that teachers will have a defensible theory or framework of assessment. There is little evidence that this is the case. It is not unreasonable to suggest that assessment, by which most teachers understand examinations and tests, continues to be the after- thought of the educational (curriculum) process just as it was fifty or so years ago. In the English system when essay type answers 30-40 minutes long or problem solving exercises of similar length in engineering were the norm, students would look at past examination papers in order to predict which questions would come around again- slightly amended perhaps. Whether or not such examinations met their moral intent was only discussed in terms of their fairness in terms of the marking systems that were used. Final judgements of their validity and reliability were left to external-assessors, a system that itself was not terribly reliable [15]. It came to be accepted that students could have a bad day when they sat their examinations for which reason coursework (continuous) assessment began to have a significant role in the assessment of performance. In contrast in the United States students were exposed to regular testing and evaluation through homework assignments. Tests were mainly of the objective type. Even in such tests it would possible for students to try and predict the type of items that would appear in a test. It came to be understood that the design of examination questions and test items influenced the strategies that students used for their learning. Using the terminology of Scandinavian researcher's, assessment could influence the students to take either a *depth* or a *surface* approach to their learning [16].

Examinations and tests have moral intent not only because they may condition student learning but primarily because they are used to judge the performance of candidates for the purpose of predicting subsequent performance; for which reason prospective employers use the data to predict the potential of students to work successfully in their organizations. It is incumbent, therefore, that a university teacher has a philosophy of assessment that he or she can stand over in the court of natural justice, for his or her judgements can have a drastic effect on the future opportunities of the students they assess. It follows that those responsible for accreditation have the same obligation since to a greater or lesser extent they dictate the attitudes that teachers bring to assessment. Given that the regulators will for the most part be peers of the instructors it is not unreasonable to suggest that they will bring the same attitudes to their regulatory work.

It is argued here that both parties have a moral obligation to act on the available knowledge and understanding of assessment and its role in the curriculum process, taking into account its historical development. For the purpose of the argument presented here that knowledge and skill may be divided between knowledge of technique and knowledge of process.

III. Technique

Technique embraces on the one hand the methods of calculating reliability and evaluating validity, and on the other hand the design of examination questions and test items. There is an easy transfer to be made between reliability in manufacturing and reliability in testing: engineering educators are familiar with Cronbach's Alpha Coefficient. The term "risk" is seldom used in the assessment literature. Perhaps this is because the general principle is to design examinations and tests that have high reliability thereby reducing the "risk." However, as it has been realized that mixed techniques of examining are better able to test for a wide range of outcomes, it has become necessary to accept that some reliability may have to be traded-off. For example in projects students learn different skills to those that they might learn in a taught course that are equally as valuable, maybe more valuable. In these circumstances it may be considered that semi-criterion referenced schedules (rubrics) that may be less reliable should be used because of the perceived advantages of the project [17]. Some argue that they may be more valid. It is the search for validity that led to the objectives (outcomes) movement. In the recent literature on assessment in engineering there are few references to validity. It seems that if an objective (outcome) is stated in terms of what a person is able to do that there can be no question about its validity. One recent study that found similarly to a study conducted nearly fifty years ago shows that statements of outcomes were understood differently by students, instructors, and the authors of the outcomes [18]. There is an obligation on those who design and use tests to ensure they have construct validity. Finally, in spite of the demand that students should be able to solve "wicked" problems there is very little in the engineering literature on the design and evaluation of such problems.

IV. Assessment and the Complexity of the Curriculum Process

If it is, as has been asserted in the previous section, assessment is the afterthought of the educational process then it can hardly be understood to be integral to the curriculum process: yet, if it is to ensure that the objectives (outcomes) of that process are achieved by the students,(the task of assessment, then the objectives of learning have to be the same as the objectives of assessment. How the aims of educational objectives (outcomes) consequent on those aims are determined is therefore a major activity that has moral intent. It is possible that objectives might be set that cannot be fairly assessed because the curriculum as designed would not enable them to be obtained in full measure. For example, it has long been understood that if the objectives of learning and instruction are not the same as those for assessment it is anyone's guess as to what the assessment measures, or for that matter what the curriculum is doing. Recently in engineering education in the US this has come to be called "alignment" but it is by no means clear that the implications of "alignment" have been fully understood because the method of instruction used does not always seem to be congruent with the learning required for the objectives (outcomes) to be obtained. For example, it will not be possible to assess critical thinking if the students are not given the opportunity to think critically.

As indicated above it is well understood that students will focus their learning on the type of questions they expect to be set. If they are focused on *surface* understanding then there is no reason for them to pursue a *deeper* level of understanding for that particular test. If a *tabula rasa* approach is taken to instruction then it is likely that some students will never pursue study in depth, and in consequence, find "wicked" problems difficult when faced with them. The point to be made is that the objectives set may be out of alignment with what students can achieve because of the ways in which they learn, and the method of instruction given. It is this misalignment which should be central to any discussion of curriculum overload. There is no point in covering a large number of "fundamentals" if (some) students are unable to understand them because the time for learning and methods of instruction do not match their learning needs. But such needs have to be understood in terms of their cognitive and affective development. Irrespective of which model of development is considered they are based on the premise that students go through stages of development in pursuit of the skills of higher learning, and that instruction and assessment has to be designed to help them proceed from one stage to the next. In sum, statements of outcomes and assessment design should take into account the ways in which students learn and develop toward the achievement of the aims of education as specified. Related to this is the question of the ability of a university program to produce graduates who can take up positions in industry without further training.

V. Answering the Question -Theories of Competence

In the first instance many educators believe that "Competencies are the result of integrative learning experiences in which skills, abilities and knowledge interact to form bundles that have currency in relation to the task for which they are assembled" (cited by Mistree, Ifenthaler and Siddique, 2013 [19]. Therefore, they can be taught and industry can tell colleges what competencies it needs. It is very similar to and in the tradition of the Aristotelian view of learning that considers the mind to be a *tabula rasa*. As Griffin [20] writes, "individual actions result from the attributes of the person that are activated and then, cause behavior. Accordingly competence is located 'in' the

individual, 'in' the mind, 'in' the brain. This view of competence is active, as in the machine metaphor, it cranks, works, churns, and then out comes the solution to the problem." This view is deeply embedded in the Western psyche and would seem to underpin the desire for "outcomes" approaches to the design of the curriculum. Such models emphasize performance rather than competence *per se*. Major questions for those who take this view are, "is concentration on the learning for particular specialized competencies (1) likely to limit the student's skill in the transfer of learning, (2) impose constraints on the curriculum's potential to enhance a student's growth (cognitive and affective), and (3) do they wish to measure performance rather than competence?"

The opposite to this "inside" view of competency is one that considers that competence is developed in a social context and depends on the relationships that a person has with others. Writing of nurses Griffin says that in, "*clinical practice, student nurses will not master the clinical environment independently, they will seek the social engagement of others to obtain feedback on whether they are meeting the expectations and standards of others in order to become members of the community"* [20]. In engineering teamwork competencies are learnt in teams but the question that has to be answered is "does team learning develop a "complete" competence that transfers to a new situation without further learning?" It is argued here that the educational context is different to the industrial context and that new learning is required. How such learning should be supported is a different issue.

Support for this argument is to be found in two European studies. The first was in France at a College created for the continuing education and training of technicians to become engineers for the automotive industry using a cooperative structure. From the literature the investigators found that competence was recognized at three levels, the individual, the group with whom the individual works, and the organization in which he/she works. Blandin writes that "at the group level, competence has an identity level: when an action is performed according to the best practices in use in a professional group, it is recognized as such by peers […] it generates a feeling of belonging to the group" [21]. At the organizational level an individual is recognized by title, level of salary, and field of action. Knowledge, skills and procedures relate to and are affected by the context and indicators of competence. This was confirmed by a longitudinal study across the three year curriculum that found that the cognitive dimension of competence had five main competency indicators of which one was found to be the core competency which was more important than the others: steps in developing a competence are driven by this core competence. The study indicated that this core competence "develops only within the company and cannot exist without long experience within a company." This is not to say that the development of competencies does not take place during the program of education and training but both the education and training experiences have to be carefully designed since the learning experiences are closely related to the development of an individual's identity. These results place a limit on what an organization can expect from formal education, and place obligations on the organization for the future development of the individual

In the second study, in order to understand the nature of competence a study was made of engineers at a Volvo engine plant whose task was to develop engines by optimizing a range of qualities such as drivability, fuel consumption, emissions and engine power." Sandberg [22] discovered that among this group of engineers there were three conceptions of what optimization meant. The first conception revealed was that of engineers who optimized the parameters separately.

The second group of engineers looked at the engine as a system of interacting parameters so they asked questions about the effect of changing one parameter on the others. The concept of optimization found among the third group of engineers related the customer's requirements (experience of driving) to the qualities of the engine. They wanted to adjust the parameters to allow for all situations in which customer's drive their cars. Sandberg argues that the level of competence differs between the three types of conception and that the levels are hierarchically ordered. Sandberg suggests "that the basic meaning structure of workers conceptions of work constitute human competence." It follows that the basis of training should be with the conception that the worker has of his/her job. This is quite contrary to the idea that attributes can be developed independently of the work organization in college for it is clear that performance of a work-based competency is a function of the perceptual match that the worker has with his task. Competency is context dependent. To understand one's place within a competency and how one could be repositioned demands capability in self-assessment which a college program can help develop. This would explain some of the difficulties experienced by young graduates when they enter the workplace that Korte found [23]. They had not been prepared to develop contextual competence that is to negotiate the industrial context in which they find themselves. Hence the value of cooperative (sandwich) courses and internships that provide students with a variety of tasks.

VI. Adult Developments

Theories of adult development clearly have a bearing on the questions asked. This point is illustrated by Torbert's taxonomy of developmental positions for professionals, especially managers [24]. It comprises 5 main frames. There is some similarity with the Perry model in that the frames move from stages of concreteness and conformity to capability in abstraction and a willingness to tolerate ambiguity. Torbert's first frame is called "*opportunistic*". To simplify, the current way of knowing of the opportunistic is the only way to view the world. According to McAuliffe (p 487), opportunistic persons "*experience others without empathy, as objects to be manipulated*" and "*tend to use force and deception to reach short-term ends*"[18]. One positive aspect is that their self-interest can force them to become entrepreneurs (my interpretation). The second frame is called "*Diplomatic*".

Professionals operating in this frame are "company men" who have loyalty to the rules of the organization but they find it difficult to make awkward decisions.

The third frame is called "*technician.*" It has a direct bearing on this discussion. To cite McAuliffe "*Technician professionals are narrowly focused on efficient methods and the internal logic of objective standards. In the process technicians fail to see the larger systems of which they are part, for they are enamoured of the consequence of their own doctrines. To them, there is no room for alternate explanations. Their logic is the only logic. Fisher and Torbert (1995) propose that technicians embrace of "standards" can be inspiring for co-workers"*[24. p 489]. Technician professionals are single minded. This frame provides an explanation of professional behavior of many engineers.

The other frames are "*Achiever*" which is held to be a wider-frame that of the "technician". They are guided by the goals of the field beyond their own career expectations and can provide leadership. The final frame is the "strategist". McAuliffe uses a comment by a manager in one of Torbert's papers to describe the *strategist* as moving from "*having very explicit goals and timetables [and] a structured organization to...the collaborative process[which] focuses on inquiry, constructing shared meanings from experience and building consensus through responsible interaction*" (p 401). Each frame is more comprehensive than the one that precedes it.

McAuliffe argues that expertise (competence) depends as much on the ability of "*how to know*" as it does on "*what to know*." Clearly this supports the view that students should be helped to acquire skill in learning-how-to-learn that include self-assessment since the ability to reflect would be essential to strategic activity. But students have also to be given the opportunity to manage themselves if as McAuliffe suggests professional competence describes individuals who have" the ability to rely on self-defined procedures to make decisions".

McAuliffe argues that "*current educational and in-service training programs teach to the technician worldview, with its ideological tunnel vision and disinterest in stepping outside of professional standards. Thus, such professionals remain embedded in the usual practices of their own fields and are less attuned to the situational contextual dynamics that professionals must account for in good portion."*

My interpretation of Donna Riley's view expressed in her Distinguished Lecture at the 2016 ASEE annual conference which was heavily critical of the proposed changes to the ABET Criteria is that they would narrow the focus of engineering education, and in consequence not help students develop beyond the technician frame.

Apart from the need for those engaged in education and training to have a defensible theory of adult learning Torbett's model faces industry with the task of clarifying what it wants from students in terms of their development. The fundamental question they have to answer is "do they wish students to develop beyond the third frame?

VII. Conclusion

It has been argued that policy decision making in engineering education is too often based on beliefs and prejudices acquired from personal experiences of the individual of education. To this might be added the peer group of engineering educators. Anything likely to create dissonance is shut out. The evidence of engineering education research is not seen to influence decision making or the majority of engineering educators. It is further argued that if there is a body of knowledge relevant and available to engineering education that decision makers have an obligation to consider that knowledge in their decision making. This applies equally to each educator. But successes are more likely to be due to luck rather than good judgement. This implies that substantial training is needed. It is also argued that one of the reasons why it is so difficult to implement change in engineering education is due to a lack of prior knowledge and training.

To illustrate these points the question of whether or not traditional four year university courses should produce graduates who are immediately employable in industry was examined. The discussion was set within the context of the moral intent of assessment. A distinction was made between the techniques of assessment and curriculum process. The point was made that there are relatively few studies of the validity of outcomes assessment procedures, but the focus was on the complexity of the curriculum process in which assessment is an integral component. In order to answer the question it is necessary to consider the nature of competence. Two theories ("outside" and "inside") that depend on different views of learning were discussed. One ("outside) suggests that some important competences continue to develop in industry while others are acquired in industry which raises questions about the responsibility of industry for the cognitive and personal development of their employees. While this theory supports cooperative structures between education and industry during four year programs it has profound implications for the design of the curriculum and the integration of programs concerned with the development of the individual in it. The other theory ("inside") considers that competences can be taught *tabula rasa*. In sum it is argued that the derivation of outcomes depends on a substantial understanding of the theoretical frameworks of assessment and student/adult development.

The divorce between theory and practice may not only put those responsible for training in industry at odds with engineering educators, but as we saw at the 2016 annual of conference of ASEE, regulators against those who deliver the curriculum.

For professionals not to use the knowledge base that is available is morally irresponsible just as it is for them not to encourage the development of that base. A primary goal of those responsible for higher education should be to accredit schemes of training for all educators and policy makers that have as one of their primary goals the provision of that knowledge base.

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