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Development of a work-based learning MSc course which incorporates the development and demonstration of professional engineering competence standards

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Abstract: *UK engineering standards are regulated by the Engineering Council (EC) using a set of generic threshold competence standards which all professionally registered Chartered Engineers in the UK must demonstrate, underpinned by a separate academic qualification at Masters Level. As part of an EC-led national project for the development of work-based learning (WBL) courses leading to Chartered Engineer registration, Aston University has started an MSc Professional Engineering programme, a development of a model originally designed by Kingston University, and build around a set of generic modules which map onto the competence standards. The learning pedagogy of these modules conforms to a widely recognised experiential learning model, with refinements incorporated from a number of other learning models. In particular, the use of workplace mentoring to support the development of critical reflection and to overcome barriers to learning is being incorporated into the learning space. This discussion paper explains the work that was done in collaboration with the EC and a number of Professional Engineering Institutions, to design a course structure and curricular framework that optimises the engineering learning process for engineers already working across a wide range of industries, and to address issues of engineering sustainability. It also explains the thinking behind the work that has been started to provide an international version of the course, built around a set of globalised engineering competences.*

Introduction

This paper details the early stages of an engineering education project that seeks to integrate the development of professional engineering competences with the acquisition of engineering academic knowledge and understanding, and addresses the identification, application and verification of a suitable pedagogy, capable of reconciling a work-based, competence-driven learning framework with the need to gain high-level knowledge and understanding.

The project is a national initiative led by the Engineering Council (EC) designed to increase the number of engineers seeking professional engineering registration. It uses work-based learning and the associated techniques of learning contracts to provide a structured set of practical engineering activities designed to build both academic knowledge and understanding at the same time as the demonstration of engineering competences. The first phase of the project involved four universities and three professional engineering institutions. It started in August 2006 with Kingston University as the lead academic body charged with producing the pilot programme and a framework for subsequent adoption by the other universities. The first author was appointed as Kingston University's MSc Professional Engineering Programme Director and EC Project Manager in November 2006, with the first students enrolling on the pilot course at Kingston University in November 2007. During 2008 students were enrolled on courses at the other three first phase universities. The Kingston course very quickly demonstrated demand with recruitment being twice that targeted, and it received very positive feedback from participating engineers (course students) and their employers. Another paper being delivered at this conference presents the existing work that has been done, and is still ongoing, in evaluating the success of the various courses at all the universities in meeting the needs of employers and students, and the original EC project goals.

However, also during 2008, in spite of the apparent early success of the course, the first author became aware of the limitations of the existing underlying education theory supporting the work-based learning practices being used and began a programme of research aimed at establishing a more compelling foundation. This led to the development of a central notion of critical reflection being integrated into the course and the subsequent introduction of Professional Supervisors to engage the participating engineers in critical dialogue. Although it is early in our work to be producing such a paper, the authors consider its production to be part of the work itself, through generation of critical dialogue with other engineering educators, with the aim of enhancing the critical reflection theory.

A key aspect of work-based learning is the attempt to build linkages between theory and practice, and the project itself is intended to be theory-supported practice. Jarvis (2004) discussed the relationship between practice theory and research, specifically in relation to adult education. In particular, given the amount and complexity of current knowledge about the subject, he questioned the extent to which theory can be applied to practice, and hence argued that in many situations a personal theory is generated by experience of practice. He noted a similarity with Argyris and Schon's (1974) concepts of espoused theory and theory in use, and the possibility that there may exist little congruence between them. Drawing on the ideas of Polyani (1967) relating to the difference between tacit and explicit knowledge, and of Nyiri (1988) relating to the generation of expert knowledge by a combination of explicit knowledge acquisition and practice, Jarvis further argued that an educational theory could be constructed from information about practice, resulting in a body of educational knowledge.

This work is being carried out in accordance with these ideas, and seeks to produce an element of practitioner generated learning (or educational) theory about work-based learning to contribute to a wider body of adult educational knowledge.

In 2009 the second phase of the project started with other universities and more professional engineering institutions joining. Aston University validated their version of the programme in July 2009 under the direction of the second author, and the first author took up the post of MSc Professional Engineering Programme Director at Aston in January 2010. Aston's version of the course is enhancement of the Kingston version, developing further the underpinning theory of critical reflection but also incorporating further refinements to the construction of individual learning contracts. The first Aston student enrolled in January 2010 and at the same time Aston also began the first serious steps towards an international version of the course.

Together with relevant background material, this paper provides a review of the pedagogical enquiry undertaken to date, which underpins Aston University's development of professional engineering work-based learning courses for both UK and international delivery.

Background

The number of engineers applying for registration with the Engineering Council as Chartered Engineer declined steadily for a number of years, and the age profile of registered engineers has gradually increased, with approximately 20% being over the age of 65, nearly double the figure of 20 years ago.

The requirements for registration as a Chartered Engineer are detailed in the UK Standard for Professional Engineering Competence published by the Engineering Council (2010). The three components of the required engineering competence are identified as education, professional development and the ongoing maintenance of competence. Under the education part of the standard, acquisition of appropriate engineering knowledge and understanding is required. Although it is recognised that formal engineering education programmes are only one way to achieve this, the exemplifying educational qualifications for Chartered Engineer status are identified as being equivalent to either an accredited integrated MEng degree or an accredited Bachelors degree with honours plus either an appropriate accredited Masters degree or appropriate further learning to Masters level.

In 2004 the exemplifying standard was raised to this level from just an accredited Bachelors degree with honours, as part of an initiative aimed at increasing the professional competence levels of Chartered Engineers, which although desirable in itself has significantly increased the challenges facing those seeking full professional engineering recognition.

Under the professional development part of the standard there is a requirement for engineers to demonstrate the achievement of a set of five general competences. Before the changes to the standard in 2004, it was normal for the development of educational competence to take place prior to the professional development of the engineering competences. For those engineers working in large engineering companies, the professional development would in most cases take place within an accredited graduate training and development scheme, in which they would also receive suitable mentoring by senior and experienced engineers.

However, under the post 2004 standard, it is recognised that the educational development and the professional development can be untaken concurrently, although still with a requirement for appropriate mentoring.

For those engineers working in small engineering manufacturing firms there is unlikely to be the opportunity to be part of a formal training and development programme and the access to suitable mentoring is also limited. It is believed that this has also contributed to a deficit in the number of applicants for Chartered Engineer status. (Engineering Council, 2008)

The Engineering Council Gateways Project

The Engineering Council are the Gateways Project leaders having co-written the original Project Submission document with Kingston University. The EC provided the purpose and management structure for the project and Kingston University the academic delivery expertise. Under EC direction a Steering Group and a Project Committee were set up in 2006 to initiate the necessary actions. Three other universities, Hertfordshire, Staffordshire and Northumbria were invited to join the project, along with three Professional Engineering Institutions (PEIs), the Institution of Mechanical Engineers (IMechE), the Institute of Engineering Technology (IET) and the Royal Aeronautical Society (RAeS).

The original ambition of the project was to provide a set of work-based learning courses that would lead to all three professional engineering status levels: Chartered Engineer, Incorporated Engineer and Engineering Technician. The early work of the project focused on establishing a detailed framework for a common course for delivery by all the universities and production of a Guide that would document this framework. However, it became apparent that this would require a high degree of complexity to accommodate all the differing organizational aspirations and systems. In early 2007, therefore, it was agreed to produce a much reduced Guide document, an MSc Professional Engineering Guide, which only addressed the requirements of a work-based learning MSc leading to CEng registration, and which contained only a set of key principles, sufficient to meet the requirements of the EC and the PEIs. This Guide would then become an EC document. Conformance to the requirements of this Guide would be necessary for any subsequent university to deliver a version of the EC MSc Professional Engineering course. This would then be supplemented by each university producing a corresponding MSc Professional Engineering Operating Manual which they would own, and which would detail all the specific criteria, organizational arrangement, operating procedures and quality assurance processes specific to themselves and the version of the course they wished to run. A further EC Guide would be produced later for a BEng Professional Engineering leading to IEng status.

This revised approach allowed rapid progress to be made by Kingston University in developing their specific version of the MSc Professional Engineering, and allowed the other universities to proceed at a rate more appropriate to their circumstances.

Subsequently the EC managed the further development of the project by co-coordinating the activities of all the universities and providing a vehicle for their engagement with the PEIs. There were two particularly significant issues that needed to be addressed. Firstly, the recognition that all the courses that the various universities deliver will ultimately need to go through some form of accreditation process. The existing arrangements used by the various PEIs to accredit courses are not compatible with a work-based learning programme such as the MSc Professional Engineering. The EC convened a conference in November 2007 to consider this matter. The outcome was an agreement by the PEIs that they would sign up to a PEI Protocol, which, whilst not guaranteeing that any engineer successfully completing a Professional Engineering MSc would be granted CEng status, committed PEIs to not disadvantaging any engineer in their application for CEng status by a requirement to produce any additional activities, so long as a series of clearly defined quality assurance steps had been achieved by the participating engineer during their MSc course. Secondly, the need for, and role of, mentoring for engineers undergoing professional development concurrently with educational development. This has been resolved by the EC undertaking to produce guidance on mentoring and a system of universities signing up to an Higher Education Institution (HEI) Protocol, as a similar commitment by to that made by the PEIs, in which they, the universities, commit to ensuring the participating engineers do receive appropriate mentoring, whilst not prescribing the actual mechanism for the delivery of that mentoring. Both the PEI and the HEI Protocols have been published by the EC and are available on their website, along with both the MSc and the BEng Guides.

The Gateways Project has now progressed to the second phase when the EC are rolling out the programme to further universities. They are reconstructing the managerial structures for the project, widening participation of the committees, and embarking on a marketing strategy. Aston University now has a role in these activities.

The Development of the MSc Professional Engineering Framework

The framework for the MSc Professional Engineering evolved out of the Kingston University's experience of running a work-based learning MSc Technology programme since 2002. This programme had proved successful in its ability to meet the needs of a wide range of students from many differing backgrounds. It uses an individually prepared and approved learning contract, split into a series of goals, with each goal being allocated a number of credit points. For a complete MSc 180 credit points are required. For each goal there are identified learning outcomes, and descriptions of the learning activity, the deliverable work the student has to produce for assessment, and the assessment criteria to be used.

The MSc Professional Engineering framework adopted this as its basic structure but also included a requirement to map the engineering competences onto the learning contract. During the development discussion it was recognised that rigid adoption of the Kingston model would not be suitable for all universities wishing to run the programme. Therefore a minimum set of required principles was agreed as follows:

- The programme must rely on work-based learning, though not necessarily exclusively.
- The programme must conform with QAA level descriptor learning requirements and engineering subject benchmark statement and the UK-SPEC requirements for a Masters degree for CEng.
- Every student starting on the programme must complete a professional development audit (PDA).
- Every student ends their course of study with an evaluation of their overall completion of their learning goals.
- Every programme will be validated by its delivering HEI and will be subject to all of that HEI's quality assurance processes.

Conformance with this set of principles then allows each HEI to develop their own set of operating procedures as best suits theirs, and their student's, needs.

The Development of a Learning Theory

The pilot programme involved the generation of learning contracts for engineers from a range of industries, with a range of academic and practical backgrounds, working at various levels of responsibility. In each case it was possible to construct a learning contract which met the academic requirements of an MSc level programme and which covered the full range of engineering competences. However, it was in each case necessary to work up the learning contract from scratch, which was very time consuming, sometimes taking as long as nine months. The process of developing their own learning contract, under the guidance of their supervisors, was very difficult for the participating engineers; it was something they had no experience of, and were unsure of the expectations of outcomes. Although all the learning contracts produced did have commonality in that they met both the academic requirements and engineering competence requirements, there was a lack of common focus to describe to the participating engineers the objectives of the learning contracts. Whilst reflecting on this problem during discussions, it was also difficult for supervisors to concisely and consistently express their objectives in the development of the learning contracts. During these discussions supervisors also found it difficult to describe a specific teaching and learning theory being used by the programme other than just to describe it as experiential learning. Although the learning experience being generated by the learning contracts and the output expectations of the goals they contained were clearly at masters level, the knowledge of this held by the supervisors was tacit knowledge as opposed to explicit knowledge.

Reviewing the literature on experiential learning provided little rigorous evidence for a reliable theory of learning other than Kolb's experiential learning cycle (Kolb 1984), which, when taken in conjunction with learning style theory, provides the foundation of the learning theory typically adopted by work-based learning trainers (Taylor and Furnham, 2005). This model of learning seemed to provide a starting point but did not adequately describe the full range of learning being encountered.

Work by Moon (2004) on the use of reflection within experiential learning gave valuable insight into the various levels of reflective ability: what she describes as "depth of reflection", from level1, "descriptive writing", the lowest level, through to level 4, "critical reflection", the highest level. Her account of descriptive writing was typical of the first pieces of work being produced by the participating engineers at the start of their PDA. Our expectations of the type of reflective ability demonstrated by Chartered Engineers and students completing a Masters level programme corresponded with her view of critical reflection. Using her model, our course would need to provide a development pathway for participants through her levels 2 and 3, “descriptive reflection” and “dialogue reflection”, respectively.

Work by Brockbank and McGill (2006), on using reflection as part of the mentoring process, led onto our consideration of the levels of learning we were trying to achieve. Brockbank and McGill describe three levels of learning: improvement, transformation, and learning about learning. Improvement learning can be brought about by reflection within an experiential learning cycle as described by Kolb. This level of reflective learning is necessary for ongoing organisational success within a continually changing engineering environment, and should therefore be part of any educational development for Chartered Engineers. However, Chartered Engineers are also the elite of the engineering profession and are expected to be able to lead the design of solutions to engineering problems “through innovation, creativity and change”. Hence they should also be able to engage in Brockbank and McGill’s transformation learning, where they “reconsider their work in strategic terms, questioning and challenging existing patterns”. This type of learning is characterised as “double loop learning”, a concept they attribute to Hawkins. Brockbank and McGill describe double loop learning as a process whereby new knowledge is created, where tacit knowledge is made explicit, and where innovation creates a new aspect to the world through new insight.

Schon’s (1983) work on reflection describes a transformation from what he calls “technical rationality” through to reflection in action. The concept of technical rationality inherently underpins professional engineering practice but his suggestion that all design activity can be modelled as reflection in action, where a designer engages in a reflective conversation with the problem situation, is an interesting and useful idea for engineers when engaged in engineering design.

The idea of the transformation of knowledge from tacit to explicit, as first put forward by Polyani (1967), also corresponds well with the activities of professional engineers, and the process of good engineering design. Interestingly, it also corresponds well with the ideas the course supervisors struggled with in defining the learning theory for the course.

Professional Mentoring

The learning theory described previously has been developed with the intention of enabling engineers continually to enhance their engineering capabilities, appropriate to the general ideas of lifelong learning and employer engagement strategies. A key part of the theory is the critical dialogue which is used to engage the engineer in the process of multi-perspective critical reflection, and the seeking out, articulation and making explicit of acquired tacit knowledge.

The requirement for mentoring of a student engineer would appear to offer the most logical opportunity for engaging in critical dialogue. However, this is not a typical mentoring activity. Prior to the development of this MSc Professional Engineering programme, mentoring has usually been a relatively unstructured process, carried out either by volunteer mentors provided by a developing engineer’s PEI, or, if the developing engineer is employed by a company with an accredited graduate training and development programme, by a senior engineer from their employing company. In both cases it is not unusual for the mentoring to consist of little more than a regular (or sometimes irregular) meeting, in which the developing engineer explains what they have been doing and the mentor then gives some advice. Ideally of course, mentoring should be, and sometimes is, far more valuable and structured; training for mentors and guidance for how to carry out mentoring is available from some PEIs, but at the cost of both fees and the mentor’s time. In the experience of the first author, mentoring is, therefore, not generally used in any consistent or coherent manner. To change the mentor’s role, so it is less about providing guidance and direction to the student engineer, possibly on a number of levels, into one which becomes a far more substantive part of their development, by engaging them in critical dialogue, required a fresh approach to mentoring. If it was to become a key part of an MSc Professional Engineering programme, the mentoring itself would need to be put on a professional footing. Specific processes, objectives, quality assurance, training, feedback and reporting mechanisms would have to be developed. Work and discussions with a number of senior members of various PEIs led to the instigation of a project to develop the mechanisms. The early work was supported by funding from the South London Lifelong Learning Network. The engineers themselves worked through the development of these processes as independently as possible from influence by Kingston University. It was important for the mentors to not be seen as surrogate academic supervisors; instead they should have a specific focus on developing the professional expertise of the student engineers, whilst all academic direction and assessment of student engineers' capabilities would remain with an academic supervisor.

The processes developed by the senior engineers, whom we now started to designate as Professional Supervisors, have been established and are being used successfully to provide a highly valued component of the course. All Professional Supervisors have to be Chartered Engineers, undertake their mentoring activities in accordance with the guidance provided, and provide a feedback report, which is peer reviewed, after every mentoring session. This last element has generated some debate, because it would appear to break one of the normal tenets of mentoring which is confidentiality. However, the student engineer is made clearly aware that a report is being produced and they are provided with a copy of it, and should they wish to avail themselves of any confidential mentoring, this can be made available as an addition to the professional supervisory role.

The guidance provided to the Professional Supervisors has not yet included material on critical dialogue other than in a general sense. Work now being done as part of Aston University's desire to provide the highest quality of course will develop a set of structured questioning techniques that will give Professional Supervisors a framework for engaging the student in critical dialogue. It is envisaged that such practice will be introduced in October 2010 following a training session on its use for all the Professional Supervisors. As part of the process of developing this framework, the course team sees in addition a need to consider the significant aspect of globalisation of engineering competences.

Globalisation and Internationalisation

In a paper presented at Engineering Education 2008, Allan and Chisholm (2008) argued that in an increasingly globalised world, where the practice of engineering transcends national and cultural boundaries, there is a growing need for a set of globalised engineering competencies. The authors concluded with proposals for a model for developing such a set of competencies.

Unlike classroom learning, the very nature of work-based learning is that it contextualises learning within the work place. If that workplace is different the learning arising will be different. This is not normally a problem because that is the intended objective of work-based learning – it generates workplace-specific learning of value to the engineer and their employer. However, if we not only vary the location of the workplace but also its cultural context, as will occur if a course is run internationally, there may be a significant impact upon the value of the learning being achieved. The underlying concepts and cultural values of the course have been based in the UK, using UK-specific engineering competences. Whilst these do have a wide international acceptance, we cannot be complacent and assume they are valid for all cultural contexts. If, as argued by Allan and Chisholm, there is an urgency to address globalised engineering competencies within a traditional classroom-based engineering educational system, there must be an even greater urgency for work-based learning practices. There has been significant interest, from both overseas students and UK students who are working overseas, in enrolling on the course. Its very nature makes it a suitable choice for engineers working in varied and changing environments, such as consulting and project engineers. Other obvious areas are in the military services, marine engineers and engineers working for mining and oil and gas exploration companies. Aston University has already started to engage with such companies to produce solutions to their engineering expertise development needs using the MSc Professional Engineering programme. These initiatives all need to be supported by a model of engineering competences that addresses the globalised engineering agenda.

This model of engineering competencies may indeed follow Allan and Chisholm's suggestions, but it cannot be generated by engineers working in one context alone. It needs to be produced by engineers from differing engineering cultures and contexts that it aspires to encapsulate. It is suggested that a basis of engineering work-based learning, such as the MSc Professional Engineering, and the forthcoming work-based BEng Professional Engineering, could provide suitable vehicles for this process, and debate, to start. Courses such as these will provide a clear focus for that debate, and also the urgency for the debate to deliver outputs. Clearly such outputs would not provide all the answers, certainly not a general solution, but a scheme for work-based learning engineering education would certainly move the issue forward. The presently used UK competences can be taken as the starting point and remodelled as required, potentially stimulating the generation of alternative ideas.

Aston University has begun the process in a small way by looking for collaborative partnerships with overseas universities who are interested in running their own versions of the MSc Professional Engineering programme, and by putting into the engineering education arena these ideas at a early stage of development so that others can have the opportunity to become involved also.

Summary

In parallel with raising the educational qualification level required, the UK has seen a decline in overall Chartered Engineer (CEng) registration. To counter the implied strategic threat to UK industry, the Engineering Council has promoted MSc Professional Engineering courses that let participants achieve CEng requirements through work-based learning undertaken during full-time employment. Course design has evolved towards a standardised high-level framework to which professional engineering and higher education institutions jointly subscribe, but each participant's detailed programme is necessarily individual, raising concerns over the resources and methods needed to arrive at suitable individual learning contracts and deliver effective learning support.

We argue that solutions can be found by grounding these matters in a suitable learning theory, for which we have identified critical reflection embedded in a "double loop" process conducive to learning and competence acquisition at the strategic innovation level appropriate to full professional engineering capability. We further argue that effective learning in an MSc Professional Engineering course needs regular guidance by well-qualified mentors. Our next step will be to test the value of critical reflection in learning, through its formalised integration with the mentoring process. We have also recognised recent pressure for internationalisation of engineering education, creating a need to develop and test the applicability of our methods across a range of cultural contexts.

References

Allan, Malcolm and Chisholm, Colin U. (2008) The Development of Competencies for Engineers within a Global Context. *Engineering Education 2008 Conference*, 14th – 16th July 2008.

Argyris, Chris. and Schon, Donald A. (1974) *Theory in Practice*. San Francisco: Jossey-Bass

Boud, D. and Solomon, N. (eds.) (2001) *Work-Based Learning*. Great Britain: Open University Press.

Brockbank, Anne and McGill, Ian (2006) *Facilitating Reflective Learning Through Mentoring & Coaching*. London: Kogan Page.

Engineering Council (2008) Engineering Council UK Register News, 40, August 2008. Available from http://www.engc.org.uk/media/17657/ecuk_register_news_issue_40.pdf [accessed 16 April 2010]

Engineering Council (2010) UK Standard for Professional Engineering Competence. Available from http://www.engc.org.uk/ecukdocuments/internet/document library/UK-Spec Standard.pdf [accessed 8 February 2010]

Jarvis, Peter. (2004) *Adult Education & Lifelong Learning*, 3rd edition. London and New York: Routledge-Farmer

Kolb, D. A. (1984) Experiential Learning, Englewood Cliffs, NJ: Prentice Hall

Moon, Jennifer A. (2004) *A Handbook of Reflective and Experiential Learning*. London and New York: Routledge-Farmer.

Nyirir, I. (1988) Tradition and practical knowledge. In: Nyiri, I. and Smith, B. (eds) *Practical Knowledge: Outlines of a Theory of Traditions and Skills*. London: Croom Helm.

Polanyi, M. (1967) *The Tacit Dimension*. London: Routledge and Kegan Paul.

Raelin, Joseph A. (2008) *Work-Based Learning*. San Francisco: Jossey-Bass.

Schon, Donald A. (1983) *The Reflective Practitioner*. London: Ashgate.

Taylor, John and Furnham, Adrian (2005) *Learning at Work*. Great Britain: Palgrave.