Outcome-based Education and Engineering Education Accreditation.

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Abstract
During the last twenty years there have been significant developments in the area of engineering education and the accreditation of these new approaches to programme delivery poses several challenges. The move from primarily input based assessment to output based assessment requires the use of different methodologies to evaluate the efficacy of learning and more importantly a different mindset on the part of educators and assessors alike. This paper provides an overview of the development of outcome based education with a practitioner perspective on the assessment process and also provides some insights as to where the impact of outcome based assessment can be further refined.

Introduction
From the early nineties there was emerging dissatisfaction with the prevailing input based education systems. The focus of these approaches centered on providing certain numbers of learning hours for each separate subject for students and set out lists of prescribed learning topics to be taught to engineering students. However there is no guarantee that exposure to the prescribed subjects will result in effective student learning and indeed there are many other factors such as motivation, socio-economic conditions which may influence student performance [1].

The increasingly globalised nature of engineering services and the work of engineers require a different skillset with more emphasis on commercial knowledge, leadership skills, cross border thinking and the ability to work in teams [2]. Additionally it was recognised that educators were preparing graduates for lifelong learning and not just for their time in university. By 2000 it was recognised that adding many of these learnings to the existing curricula would increase the duration of the time needed to educate engineers and therefore more effective and efficient ways to cover the material were required [3]. At about the same time the International Engineering Alliance had started to draft outcome based graduate attributes and many of its signatories were already implementing assessment of learnings using an outcome based approach. The twelve graduate attributes provided exemplars to which graduate engineers should be exposed so that they may become effective practitioners. The areas covered include engineering knowledge, problem analysis, environment and society, lifelong learning, project management and finance and communication skills [4].

The meaning of Outcome Based Education

There are many definitions of Outcome Based Education (OBE) but for our purposes the most useful descriptions are:

> "Outcome-based Education (OBE) means focusing and organising a school's entire programs and instructional efforts around the clearly defined outcomes we want all students to demonstrate when they leave school." (Spady, 1993)
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> "An outcome is a culminating demonstration of learning. It is a demonstration of learning that occurs at the end of a learning experience. It is the result of learning which is a visible and observable demonstration of three things: knowledge, combined with competence, combined with orientations." (Spady, 1994)

The deployment of an OBE approach to programme outcomes means that the assessment methodology needs to change to reflect the different perspective. At the outset to achieve this objective the learning outcomes must be clearly visible so that educators and students can work towards the defined program outcomes and learning outcomes.

Input based approaches have generally focused on hours of teaching in specific subject areas. The European Credit Transfer and Accumulation System (ECTS) is a standard for comparing standards and attainment of students in Europe with an academic year being equivalent to 60ECTS. However each ECTS duration can vary from 15-30 hours depending upon the country – and of course there is no guarantee that the student exposed to those hours is actually learning or daydreaming.

There is anecdotal evidence that much of what is learned at college is out of date before the student graduates – a reflection on the rapid pace of change in technology. So five years after graduation it follows that only a small proportion of the college learning remains relevant (or can simply be accessed online or a programmable module). To cope with this shift in learning it is vital that colleges teach their students to become lifelong learners – engaging in continuing professional development to keep their skills alive. In 2016 – it is beyond our thinking of flying in an aircraft flown by a pilot who has had no additional study since graduating in 1976 or have open heart surgery by a surgeon using techniques from 1970. So why should we accept this from engineers? To address this we need a different way of educating so that students understand that they need to learn and develop skills relevant to their chosen field for the duration of their active career.

A key differentiator of the outcomes based approach is that the evidence that the student has actually understood and demonstrated mastery of the learning outcome is now independently assessed. Inherent in this assessment is that the processes and facilities of the higher education institute (HEI) and the performance of the teaching staff are also being assessed. This has implications on the assessment environment and is discussed later. The training of the assessors is also an important consideration.

OBE – An Irish context

The third level education sector in Ireland consists of 7 universities and 14 Institutes of Technology (Polytechnics/Universities of Applied Science) in a population of 4.5 million or 180,000 students. Engineers Ireland accredits engineering programs to meet the requirements for professional engineers (Chartered Engineers), engineering technologist (Associate Engineers) and engineering technicians. The Accreditation Criteria [5] are outcomes based and provide guidelines to program designers on the outcomes to be achieved by students but not the methods on how these outcomes are achieved.

The accreditation criteria are supported by the ‘Procedure for the Accreditation of Engineering Education Programmes’ [6]. This document sets out the accreditation process, the documentation and evidence to be provided by the higher education institute with samples of the documents to be submitted and the reports of the assessment panels.

Because Engineers Ireland accredits all fields of engineering (e.g. civil, electrical, biomedical) the criteria and procedures do not specify how an outcome is delivered – the accreditation process must be flexible to address any situation. Assessors undergo training and ‘on the job’ mentoring from their fellow assessors during assessment visits.

Assessment of Outcomes

Engineers Ireland has seven programme outcomes and these are equally distributed between maths/engineering sciences and so called ‘softer subjects’ such as teamwork, ethics and communications. This is a reflection of the real world engineer – being technically excellent is useless if the engineer cannot communicate their ideas to a wider audience and their ideas must sit comfortably with social and ethical considerations. The programme outcomes are supported by programme area descriptors that indicate how each programme area can contribute to the overall achievement of the programme outcome. The programme area descriptors are:

- Sciences and Mathematics
- Discipline-specific technology
- Software and information systems
- Creativity and innovation
- Engineering practice
- Social and business context

With such a broad spectrum of learning outcomes combined with programme area descriptors and a potentially infinite number of pedagogical approaches to deliver the assessment of the outcome is potentially complex.

However, we must recognise that this is a peer assessment so the assessment panel is looking to see if what they are assessing is *substantially equivalent* to the programs that they deliver in their own education institutions or if they deliver to the requirements of industry.

The key Engineers Ireland learning outcomes for a professional engineer with an indication of the assessment for each learning outcome are presented below.

Learning Outcome	Typical Evidence
(a)Advanced knowledge and understanding of the mathematics, sciences, engineering sciences and technologies underpinning their branch of engineering.	• Learning level of questions being asked in exams - Bloom's Taxonomy • Is the knowledge at the correct level for this programme? • Compulsory versus optional questions
(b)The ability to identify, formulate, analyse and solve complex engineering problems.	• Learning level of questions being asked in exams • Are the problems complex and seeking exploration of a number of options • Focused lab work
(c)The ability to perform the detailed design of a novel system, component or process using analysis and interpretation of relevant data.	• Understanding of design processes • Standard industry design tools • Project work
(d)The ability to design and conduct experiments and to apply a range of standard and specialized research (or equivalent) tools and techniques of enquiry.	• Evidence of design in project work • Research into chosen project under guidance • Analysis and reflection on design
(e) An understanding for the need for high ethical standards in the practice of engineering, including the responsibilities of the engineering profession towards people and the environment.	• Use of industry standards • Evidence of sustainability in assessments, projects, student responses. • Awareness of professional bodies
(f)The ability to work effectively as an individual, in teams and in multidisciplinary settings, together with the capacity to undertake lifelong learning.	• Teamwork projects with other non-engineering participants • Graduate interviews •
(g) The ability to communicate effectively on complex engineering activities with the engineering community and society at large.	• Teamwork projects • Student's reflective journal on work placement • Final year project presentation

The assessment is evidence based and therefore the assessment panel consisting of two academics and an industry practitioner need a high tolerance for ambiguity and the ability to be flexible in their approach. The presentation of evidence for two programmes delivered by the same academic team at the same HEI can be quite different.

Today much of the evidence may be stored on electronic systems or be delivered by service departments not under the direct control of the engineering department (e.g. mathematics or science).The assessment panel will only see the evidence first hand during a short two day visit and will have to think and act fast to ensure they can provide an accurate assessment of the programme.

Assessment of Non-Outcome Factors

It should be remembered that assessing the learning outcome from students, while important, is not the only consideration of the assessment panel. The assessment panel also must consider other areas that potentially have a direct bearing on the environment in which the student learns. These include:

- The resources of the college e.g. are there sufficient teaching staff, is the laboratory equipment up to date and capable of supporting currently relevant experiments and project work. Do library services provide adequate material?
- Is the engineering programme well managed? – is there a champion for the programme in the HEI to acquire the funding and resources to keep the programme current.
- The experience of the staff. It is important that some of the staff delivering modules have industry experience and are active with industry and their professional bodies. The staff is the real life role models for their students.
- It is critical that the student experience while at college is one that is conducive to good learning. The work should be engaging and stimulating with guest lecturers, field trips and if possible work placements to show students what engineers actually do in real life. Teaching students to reflect on the workplace value of academic tasks greatly enhances learning [7].
- Similarly if students can raise concerns or suggest improvements on their experience then they will feel engaged in their studies. The relationship with their academic team is the key to a good learning experience. Of course there are many areas where the academic team cannot help (e.g. family, relationships and accommodation) but if the HEI provides a supportive network such as student services then this will support students when they need assistance.
- The progression rate of students from year to year is also a factor to be assessed – if the progression rate is low does this reflect an issue of how the programme is delivered? Poor teaching or facilities? Does it affect the viability of the programme itself?

> "The basic tenets of OBE are shifting the focus of educational activity from teaching to learning; skills to thinking; content to process; and teacher instruction to student demonstration." (Williams, Cited in Tavner, 2005)

One of the challenges of the OBE approach is that *every* part of the system, processes and people of the HEI is assessed and this can lead to a tension or wariness of the assessment panel by HEI staff – at least on the first assessment. The assessment process operates at its best in a 'high trust' environment. The assessment team are not judging to be negative but assessing the outcomes with a view to improvement. Once staff and assessment panel operate from this perspective the process becomes a win-win for all parties.

Involvement of Industry

Engineering is a practicing profession, it is therefore vital that the education of engineering students reflects the real world needs of fast paced global industry. This can be achieved in a number of ways:

- When designing programme outcomes key industrial players should be consulted.
- The Accreditation Board should have a mix of academic and industry representatives
- The composition of the assessment panels normally includes an industry practitioner
- Many HEIs put in place an industry advisory panel. This ensures that the HEI is embedded into the industry in the local area and can support industry with research projects or technology transfer.
- During the accreditation assessment process there should be interviews with employees who are graduates from the engineering programmes and employers to provide a view on how well the programme meets the needs of industry.
- The teaching staff should have some industrial experience or be working with industry on specific projects.
- The programme should incorporate guest lecturers from industry to demonstrate to students that the material they are learning is of relevance. Once students see the relevance of what they are learning they will be more engaged.
- Student work placement allows students to experience the application of their engineering studies and this experience benefits their continuing undergraduate studies.

Problem Based Learning and Future Trends

Many engineering courses now provide elements of Problem Based Learning (PBL) as part of the delivery of material. PBL is essentially a collaborative, constructivist, and contextualized learning and teaching approach that uses real-life problems to initiate, motivate and focus knowledge construction. In the PBL environment students and academic staff work collaboratively and this can be highly effective especially during the transition to learner centered from teacher center approach [8]. The PBL approach allows the incorporation of new approaches to student – teacher interaction, the exploration of complex problems in new conceptual and physical spaces. This reinforces the "shifting the focus of educational activity from teaching to learning; skills to thinking; content to process; and teacher instruction to student demonstration" – the key tenets of OBE cited earlier.

The assessment of outcomes in these evolving learning environments is both challenging and rewarding and the assessment panels need the latitude to be able to assess the achievement of the learning outcomes in context.

Though I have looked at the outcome based approach there may be more intrinsic factors that need to be considered when undertaking assessments. There is a gap in parents' and students' understanding of engineering and this means that the engineering profession and academics need to consider the public image of engineering [9]. Secondary level students entering engineering programs experience a gap between their pre-entry expectations and their first-year experiences [10]. The better students cope with this gap the better they will engage and remain with the engineering programme.

Of course, these factors cannot be assessed during accreditation visits however once they enter college if students are provided with a better understanding of what engineers actually to their understanding and motivators change. This is particularly reflected in evidence when students are exposed to real world engineers or complete work placement and ultimately, in student retention rates.

Conclusion

One of the challenges of the OBE approach is that *every* part of the system, processes and people of the HEI is assessed and this can lead to a tension or wariness of the assessment panel – at least on the first assessment. The key benefit of this approach is that we can actually see what students have learned and adapt our pedagogical approach in response to this valuable feedback.

The OBE accreditation process is one of assurance and building of trust and once this position has been established then all parties can work cooperatively to further the quality of engineering education for students and society.

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