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Engineering Education for the 21st Century: Scholarship, Synergy and Student Success.

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Abstract

Starting with the question "How can University level Engineering Education be developed in such a way so as to enhance the quality of the student learning experience?", this discussion paper proposes an approach to engineering education developed by a senior engineering educator working alongside a pedagogical researcher in an attempt to engage colleagues in contemporary debates about the issues currently faced across the Sector. Such issues include difficulties with recruiting students onto programmes as well as high levels of student attrition and failure. Underpinned by three distinctive concepts: Synergy, Variety & Relationships (S+V+R), the approach brings together pedagogic and engineering epistemologies in an empirically grounded framework in such a way so as to provide an accessible and relevant learning approach that, if followed, engenders student success [S^2].

Specifically developed with the intention of increasing retention and positively impacting student success [S^2], the $S+V+R=S^2$ approach provides a scholarly and Synergetic (S) approach to engineering education that is both innovative and exciting. Building on the argument that Variety (V) in education is pivotal to promoting originality and creativity in learning and teaching, this paper shows how, by purposefully developing a range of learning and teaching approaches, student engagement and thus success can be increased. It also considers the importance of Relationships (R) in higher education, arguing that belonging and relationships are crucial factors impacting student experiences. When taken together (Synergy, Variety and Relationships) and applied within an Engineering Education context, students are provided with a unique learning environment – one that both promotes individual success and improves organisational effectiveness. The uniqueness of the approach is in the synthesis of these three concepts within an Engineering Education epistemology.

Introduction: Learning & Teaching in Engineering - The UK Context

Defined by the Oxford English Dictionary as *'the branch of science and technology concerned with the design, building, and use of engines, machines, and structures'*, the digital revolution has meant that Engineering can no longer be considered merely as being a 'branch' of Science, instead it has become what is arguably the most vital driver of future societal advancement. As such, Engineering has strengthened its position as a Discipline and a Profession in its own right. Needless to say, such a change in ethos means that Engineering Education also has to change; indeed, Engineering Schools are no longer expected to produce Graduate Engineers looking to specialize in a single area of the Sector, but are instead expected to produce young Engineering Professionals, able to work in a fast-changing, demanding and global environment. Highly skilled and flexible individuals, young Engineers need to be equipped with critical thinking and a range of other 'transferable' skills and competencies. Yet despite this requirement, evidence exists to suggest that in the UK universities are failing to produce Engineering graduates equipped with the necessary transferable high-level skills and competencies required to succeed within the Profession (CBI, 2008; Bawden, 2010). This means that many employers are forced to look overseas to fill Engineering vacancies (Spinks et al, 2006).

Problems with attracting people into Engineering are augmented by the fact that, for some years, Engineering Faculties have experienced difficulties in firstly recruiting, and then in maintaining, student numbers onto Undergraduate Engineering Programmes (RAEng, 2007; Engineering Council, 2010; Royal Society, 2011). Indeed, it may be argued that if difficulties in recruiting and retaining new Engineers are not dealt with as a matter of urgency, the UK, and other 'Western' countries will face severe shortages of Engineers over the next thirty years, and that this in itself could have a devastating effect on our society (Spinks et al, 2006; RAEng, 2007).

SVR = S^2: A New Approach to Engineering Education

In seeking to address issues associated with difficulties in attracting, recruiting and retaining students onto Engineering Programmes, the paper authors set about developing a bespoke learning and teaching approach that would meet the learning needs and expectations of the students, whilst providing a sound pedagogical basis upon which Engineering Education could be based. Building upon Higher Education Theory, and grounded in Engineering Education Research and Practice, an approach was developed in which three key components were identified as pivotal to Student Success within Engineering. These components are: Synergy: Variety: and, Relationships

In short, the approach argues that:

Synergy + Variety + Relationships = Student Success **(*S+ V + R =* S^2)**

Bringing together previous research focusing upon student success (Thom, 1997; Berger, 2001; Upcraft et al, 2005; Kuh et al, 2006; Tinto, 2006), and building on the concept of Self-Authorship in education (Kegan, 1994; Baxter Magolda & King, 2004; Hodge et al, 2009) the researchers began by defining student success in Engineering Education as follows:

> *Student success in Engineering Education represents a dynamic mixture of intrinsic and extrinsic factors evidenced through self-authorship and high levels of student engagement in learning. Intrinsic factors encapsulate individual development as a learner manifested by enhanced self-belief and the acquisition of generic and discipline-specific know-how, skills and competencies. Exogenous factors build on a priori experiences to increase and enhance epistemological understanding of theoretical, conceptual and practical knowledge.*

This following paragraphs provide a brief explanation of the three concepts, Synergy, Variety and Relationships, explaining each one and considering how each can be applied to Engineering Education in such a way so as to promote student success. This paper is purposefully aimed at colleagues wishing to engage in debate about the issues faced across Engineering Education today. Moreover, although the emergent study findings are not reported here, it is important to note that the approach discussed is based upon ongoing pedagogical research and hence is being constantly, reviewed, evaluated and refined.

- Synergy & Student Success

The concept of *Synergy* acts as both a *Pedagogical Catalyst*, promoting innovation in learning and teaching, and also as a *Scholarly Glue*, bringing together pedagogic, discipline-related, socio-environmental and individual factors. It is achieved by contextualizing and aligning the intended learning outcomes with the teaching methods used, and by building into the curriculum a means of addressing the expectations and requirements of all stakeholders. In Engineering Education the aim is to provide students with a *Synergetic* learning experience in which the module outcomes are purposively aligned within the overall Programme outcomes. In addition to this, other external drivers such as employability, professional body requirements and other perspectives are centrally placed.

Thus, Synergy in learning and teaching is achieved and maintained through a process of firstly deconstructing, and then, reconstructing, the learning outcomes and objectives. This necessitates developing Biggs' (1993) Presage-Process-Product approach to introduce purposeful learning outcomes and objectives in which academic, individual, socio-economic, environmental and professional requirements and expectations become embedded (for further discussion see, RAEng, 2007; Leitch, 2006; Spinks et al, 2006). Whilst it is usual practice for engineering programmes to align module outcomes and professional body requirements; the concept of Alignment is further developed through the adoption of a Synergetic learning and teaching approach whereby the Intended Learning Outcomes (ILOs) far exceed the original learning outputs of the Programme, so as to equip students with the key skills and competencies needed to be Professional Engineers, engaged and active citizens *and* lifelong learners.

- Variety & Student Success

The concept of *Variety* is embedded across the curriculum by 'thinking out of the box – and out of the classroom'*.* Variety (V), relates both to originality and creativity in learning and teaching. Given the varying ways in which students learn (Entwistle & Ramsden, 1982; Biggs, 1993; Cuthbert, 2005) it is vital that all Engineering Educators adopt a variety of approaches to teaching. Such approaches need to be relevant from a professional perspective, but also fit-for-purpose so that students are able to meet the learning outcomes (Prosser & Trigwell, 1999; Fry et. al, 2009). Within Engineering Education there are countless opportunities to introduce Variety into the curriculum, with laboratories, manufacturing, fieldtrips, simulation, project-based learning to name but a few.

Whilst the concept of Variety is not new, it is important to accept that many student engineers are taught using 'traditional' methods of lectures and laboratories. Conversely, engineering innovation is rarely planned for, but instead occurs as a result of 'blue-skies' thinking and original problem-solving. If student engineers are to be equipped to work in the 'real-world' then they need to learn in an environment in which the 'unexpected' becomes the norm. Hence variety is not just about change, it is about reality.

- Relationships & Student Success

Placing *Relationships* at the centre of the learning environment, the $SVR=S^2$ approach recognizes that belonging and individual relationships (R) are essential to success in Higher Education and as such need to be valued and nurtured (Baxter-Magolda & King, 2004; Cowan, 2006; Foster, 2008). Consequently, learning materials need to be developed in such a way so as to allow the students to develop professional relationships and individual friendships. Previous studies suggest that relationships are paramount in addressing problems related to retention and transition, and that by promoting a ‘sense of belonging’ universities can do much to enhance student success (Read et al, 2003; Quinn, 2005; Pitman & Richmond, 2008).

In Engineering Education relationships can form an integral part of the curriculum. This is difficult to achieve when teaching large numbers of students. Indeed, it is easy for students to become isolated and difficult for tutors to build individual relations with every student. However, by purposefully building Group Work and Project-Based Learning into the curriculum engineering educators can provide the ideal means by which students can form meaningful relationship with both their peers and academic staff.

Discussion & Concluding Remarks

In developing and continually evaluating the $SVR=S^2$ approach the paper authors have attempted to make the ‘language and philosophy’ of educational research more accessible to Engineering Educators and Professionals. In doing they have created an approach to learning and teaching in Engineering Education that encourages colleagues to engage with the concepts of Scholarship and Self-Authorship in a meaningful way. By deliberately articulating the approach as a formula, $SVR=S^2$ moves away from the complex, confusing and complicated language common within Sociology and Pedagogic Research. In doing so, a more Engineering ‘friendly’ and appropriate model.

The paper authors believe that given the difficulties faced by contemporary Engineering Education the need to develop an ‘Engineering-friendly’ learning and teaching approach has never been more important. The $SVR=S^2$ approach is being ‘rolled out’ across a number of Engineering modules, including those offered by ‘distance learning’. In order to maintain quality in learning and teaching, plans are in place to continually and critically evaluate the approach as it is rolled out. The next stage is to develop an $SVR=S^2$ Portfolio Tool that can be used by individual Engineering Educators to evaluate and enhance their own learning and teaching. Indeed, by continually developing and critiquing the approach, and by disseminating the knowledge acquired from the ongoing evaluation, the $SVR=S^2$ approach has the potential to positively impact Engineering Education on a wide scale.

In conclusion, this paper began by arguing that as a discipline, Engineering has long played a central role in societal advancement, underpinning and leading the agricultural, industrial and more recently the digital revolutions. Indeed, we argue that society’s need for highly motivated and educated engineers has never been greater. Within this environment, the demands placed on Engineering Education to produce the next generation of Engineers, are, in the UK at least, set against reductions in university funding and increased student demand and expectations. The $SVR=S^2$ approach has evolved over a number of years to provide an approach that can be used to address such challenges as well as others associated specifically with learning and teaching in engineering. The approach is built on the belief that Engineering is vital to the future sustainability of our society. At a time of economic recession and social uncertainty, public attention inevitably turns to the Engineering Profession to provide new ideas upon which future society can be rebuilt and sustained. Engineering Education has a vital role to play in developing future engineers able to meet this demand. The three components of the approach, ‘Synergy’, ‘Relationships’, and ‘Variety’, when synthesized together and adopted concurrently can not only enhance students’ learning experiences but can also act as a catalyst to positively impact how Engineering Educators approach teaching. This ultimately contributes to student success. To summarise, the proposition ***“S +V + R = Student Success”*** provides a useful and usable approach that may be adapted to suit any area of Engineering Education.

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