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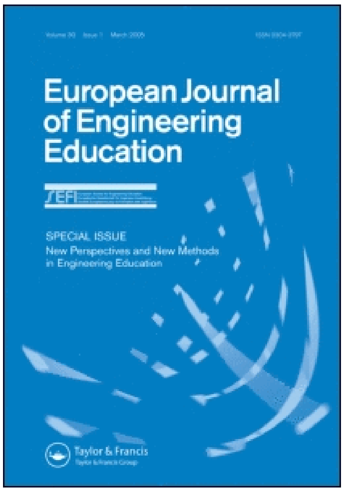

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The effect of context on student engagement in engineering

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The self-belief, motivation, tendency to procrastinate and learning styles of engineering students are discussed. It is proposed that engineering has developed an idiom and a learning approach that favours the dominant client, i.e. men, while simultaneously undermining the self-efficacy and motivation of women. Thematic coherence and teaching within a context that is familiar to students have been shown previously to be effective approaches for engaging students and are extended here to utilise the common experiences of all students to initiate the learning cycle. These approaches are combined with a template for teaching that uses the 5Es (Engage, Explore, Explain, Elaborate and Evaluate) in order to render the fundamentals of engineering more accessible to all students. This methodology can be introduced by individual instructors, who will be rewarded by students who are more engaged, more motivated and more likely to give a higher rating to the instructor and the course.

Keywords: learning style; gender diversity; student success; recruitment; retentions everyday examples

Introduction

Issues associated with energy security, geopolitical stability and climate change are putting huge new demands on the engineering profession. At the same time the challenges of recruitment and retention of undergraduate students in engineering remain unresolved and are well documented. For instance, data from the National Center for Science and Engineering Statistics (2008) show that the number of engineering degrees as a percentage of total degrees awarded in the US declined steadily from a peak of 7.8% in 1985 to about 4.6% in 2002 and has remained at that level. The situation is similar in the UK, where this percentage has declined from 6.7 in 2001/02 to 6.1 in 2007/08 (Engineering UK 2010). Global comparisons are harder to make, although data on the number of graduates in science, technology and mathematics per 1000 of population aged between 20 and 29 years are readily available (Eurostat 2010). For the US this metric shows a decline from a peak in 2003 of 10.9 to 10.1 per 1000 in 2008: a 7% drop. This compares to a

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similar trend in the UK from 21 in 2001 to 17.6 per 1000 in 2008 or a 16% decline. However, this metric for the European Union increased steadily from 8.8 to 13.9 per 1000 over the decade up to 2008, with Japan exhibiting the same trend from 12.3 to 14.3 per 1000 (Eurostat 2010). The growth in European numbers is fuelled partly by an increase of 42% to 12.5 per 1000 in Germany, where there is a gender balance, with women aged 20 to 29 years representing 63% of the graduates with science, technology and mathematics. In the European Union and Japan, women aged 20 to 29 years represented 34% and 29% respectively of the graduates with science, technology and mathematics (Eurostat 2010). A recent report from the National Academy of Engineering (Committee on Public Understanding of Engineering Messages 2008) collated data that showed that, while women represent 50.7% of the population, they are only 20.5% of engineering bachelor's degree enrolment in the United States. Historical data show no real change in these proportions over the last decade, with the percentage changing by less than 4% in Europe, Japan (Eurostat 2010) and the US (Engineering Workforce Commission 2009). The exception is Germany, where it has risen by 60% (Eurostat 2010). It would appear that there is a poor performance in attracting women into science and engineering in the US and UK, which is leading to a reduction in the proportion of the population with degrees in these subjects.

The picture is not uniform within engineering, with chemical and industrial engineering graduating cohorts being more than 30% women (Engineering Workforce Commission 2009). Meanwhile computer, mechanical and electrical engineering graduating cohorts typically have 15% or fewer women (Engineering Workforce Commission 2009). Mechanical engineering is the least gender diverse of these major engineering disciplines and it has shown little or no improvement in the last decade, with women representing less than 15% of the graduate cohort in the US (Engineering Workforce Commission 2009) and Canada (Burrowes 2006) compared to about 8% in the UK (Engineering UK 2010) and Australia (Burrowes 2006). It is clear that in English-speaking countries engineering, and mechanical engineering in particular, has a significant problem achieving a balance of men and women in the profession and this has a significant influence on the size of the profession.

To quote a past President of the National Academy of Engineering: 'as a consequence of a lack of diversity [in engineering] we pay an opportunity cost, a cost in designs not thought of, in solutions not produced' (Wulf 2002). This cost is becoming increasingly important because issues such as energy security, geopolitical stability, climate change and global competition have rendered unsustainable many current engineering solutions, i.e. products and services. The uneven global pattern of energy consumption (BP 2009) and the strong dependency on a non-uniform distribution of fossil fuels (BP 2009) threatens the external and/or internal security of many nation states. Geopolitical stability is further threatened by a likely reduction in available land as a consequence of a rise in sea levels brought about by climate change (Blockstein and Wiegman 2010) with only a 1 m rise in sea level displacing 145 million people worldwide (Nicholls *et al.* 2007). Already, the ecological footprint[1] of citizens of developed countries is five to 10 times that of inhabitants of developing nations, so that several more planets would be required for everyone on this one to enjoy the lifestyle of an American or European using current technology (Wilson 2001). It has been argued that one needs to 'avoid the unmanageable and manage the unavoidable' (Friedman 2008) and this involves finding new sustainable engineering solutions to both old and new engineering problems. The 'equivalent of 200 years of development are needed in less than 40 years' (Sakaki 2009) and this requires a larger proportion of the population to be trained in engineering and science than has been the case in the past. In turn, this requires engineering to become a more attractive option for all students.

This paper has focused on mechanical engineering, partly because of the greater need for increased gender diversity and partly because of the authors' area of expertise. However, the principles and methodology could be applied across the whole engineering profession and beyond. It is surmised that the traditional approach to teaching mechanical engineering naturally favours the dominant consumers of bachelor degree programmes, namely, men. Thus, in order to attract the interest of a greater proportion of the student population, new ways of presenting the subject need to be identified and implemented, which are more attractive to all students but to women in particular. This need goes beyond approaches to recruitment, for which it has already been proposed (Committee on Public Understanding of Engineering Messages 2008) that advertising that engineering requires a high level of aptitude in mathematics and physics is counter-productive and instead the focus needs to be on how engineers contribute to society. Messages such as ‘engineers make a world of difference’ and ‘engineering is essential to one’s health, happiness and safety’ make engineering look attractive.

Sheppard *et al*. (2009) have observed that, although in the rest of the world a profound transformation is occurring in the engineering profession, the approach to undergraduate engineering education in the United States remains essentially unchanged and is becoming disconnected from the global engineering profession. They suggest that: ‘a focus on professional practice will require remaking undergraduate engineering education, networking the components in ways that strengthen and connect them to a cohesive whole’. Here it is proposed that a more subtle change is required at a fundamental level because engineering education has developed a ‘language’ or idiom of models and analogies to which men are attuned but which excludes women; or at least makes the subject relatively inaccessible and apparently uninteresting and irrelevant. It is proposed that traditional engineering science subjects, which are usually taught in the context of idealised engineering applications, should be presented in the context of real-life examples that form part of the everyday experiences of all students. The implementation of such an approach is likely to render the subject more attractive and accessible to a larger proportion of the population, which is desirable to achieve the new sustainable engineering solutions mentioned previously.

Proposed hypothesis

The assumption is that, in order to attract and retain students in engineering courses, the courses must be taught in a context that is familiar to students and, preferably, transparently relevant to the challenges facing society. Context is used here both in its modern meaning: ‘surrounding conditions’ (Soukhanov 2002) and its old-fashioned meaning: ‘a construction of speech’ (Little *et al*. 1983). The importance of teaching engineering by reference to the surrounding conditions is perhaps so obvious that it should require no comment, except that the professors and professional engineers engaged in teaching have a tendency to forget that the formative and current conditions surrounding or experienced by their students are somewhat different from their own now and largely different from their own conditions when they were students. This difference arises from not only the greater engineering experience of the instructor but also from the cultural gap between student and professor, which is large enough to have warranted an anthropological study (Nathan 2005). Urbanisation, a shift to white-collar professions and the effect of the digital age are all contributing to this cultural gap. So it is argued here that special efforts have to be made in teaching to use exemplar applications that place engineering principles and ideas into the conditions surrounding the students on an everyday basis, particularly in the earlier, introductory courses.

It is also relevant to discuss the context in the sense of ‘a construction of speech’ since engineering education has rendered a practical subject abstract by ironically evolving an idiom of models and analogies. Evidence of this can be found in almost any introductory textbook on a topic. For instance, books on dynamics have a plethora of colliding spheres, rotating mechanisms and spring and dashpot[2] systems, while in mechanics of solids textbooks, beams, columns and shafts abound. It would be wrong to state that these examples have no relevance to the subject of study. However, the relevance is often only apparent to those well versed in the subject, which, by definition, students are not. Instead, these highly idealised models of engineering scenarios make no connections with the background of the students who have not previously worked in the field. They have a tendency to become intellectual exercises that may enhance the problem-solving skills of students but appear increasingly disconnected from their life experiences and the field of mechanical engineering, especially as the field is transformed by technological advances and globalisation. Some textbooks do not exclusively use such examples. Racing cars, aircraft and trucks, topics that have traditionally been of greater interest to young men than to young women, often appear in various scenarios with varying degrees of abstraction (e.g. Turns 2006, Gere and Goodno 2009, Hibbeler 2010). The hypothesis is that these real-life examples need to be extended by including a wider range of artefacts emphasising examples that are familiar to all potential students. In addition, there needs to be a reduced level of abstraction in order to make a closer connection to the realities of student experiences.

Background/rationale

It has been found that student success is a multiplicative function of ability and motivation (Pinder 1984, Chan *et al*. 1998) and that strong motivation requires good achievement striving – the extent to which individuals take their work seriously – and good situational expectations, i.e. optimism not pessimism (Norris and Wright 2003). These factors can be enhanced by setting engineering science in a professional context and by connections to something familiar (Sheppard *et al*. 2009) through improving curricula links to the outside or real world, such as the guest speakers and field trips identified by Koehn (1995) as highly rated by students and/or by utilising relevant exemplars, i.e. relevant to the students' everyday experience. The least effective teaching methodology is the pure lecture (Ellis and Knaus 1977), which is still quite dominant in mechanical engineering.

Also tied to student success, or lack of success, is procrastination, which is defined as 'postponing a task to the extent of experiencing subjective discomfort' (Ellis and Knaus 1977). Academic procrastination is determined not only by a student's personality, time management skills and motivation but also by situational factors such as scheduling of courses (Milgram *et al*. 1992). The latter implies that, for good progress, competition between courses should be reduced and thematic coherence should be promoted (Patterson and Johnson 1992). At the University of Sheffield in the 1990s (Patterson and Johnson 1992), the former was achieved by a rigorously applied tariff on the total workload permitted for each course, which included lectures, tutorial and laboratory classes, self-study and assessment time. Simultaneously, in the first year of the programme, the bicycle was used as an over-arching theme to provide coherence. This is a real life application, familiar to almost all students since nearly every student has a bicycle either on campus or at home. While curriculum reforms that account for factors influencing student success have occurred in many countries, in the United States progress is slow. A recent report of the Carnegie Foundation concluded that the current over-burdened curriculum is seen as an obstacle to developing engineering skills (Sheppard *et al*. 2009). This is a state of affairs that existed as long ago as 1918, when a similar report described the curriculum as 'congestion beyond endurance' (Mann 1918).

Student success is also closely related to self-efficacy (Marra *et al*. 2009), i.e. a belief in one's capabilities. Four sources that contribute to success have been identified (Bandura 1997): mastery experiences; social persuasion; psychological state; vicarious experiences. Mastery experiences include the positive experience of completing a course and the dawning realisation that one's understanding of a concept allows a new appreciation of a much observed behaviour. Typically, on average, women self-report lower competency than men of equal STEM (Science, Technology Engineering and Mathematics) competence (Besterfield-Sacre *et al*. 2001), demonstrating a disturbing gap between actual competence and self-efficacy (Marra *et al*. 2009). Social persuasion is an important factor since social support from friends and family has been shown to be an important predictor of the performance of women in physics courses (Bandura 1997), while supportive faculty increases women's self-efficacy in maths-related subjects (Zeldin and Pajares 2000). Negative social persuasion, such as statements implying one cannot or should not do certain things, is closely related to a psychological state, in which performance is reduced by anxiety arising from negative stereotyping (Steele and Aronson 1995). Vicarious experiences, i.e. via observation of someone else's engagement, are, on average, more important to women than men (Zeldin and Pajares 2000) and the effect is dependent on the similarity between the observer and the observed (Marra *et al*. 2009), whereas mastery experiences are more critical to the self-efficacy belief of men (Zeldin and Pajares 2000). So it is to be expected that mastery of the intellectual exercises involving, for instance, pin-free beams supported on a spring or eccentric impacts of spheres, will favour the self-efficacy and hence motivation of many men, while the lack of connection to observed experience in the same exercises may impact negatively the self-efficacy of many women. Social cognitive career theory suggests that outcome expectancy also plays an important role (Lent 2005). Outcome expectancy refers to an individual's belief about the consequences of given actions. The relative importance of outcome expectancy and self-efficacy on people's choices depends on the person and situation and both need to be positive in order for an individual's interest in an activity to blossom (Lent 2005). However, outcome expectancy has been found to be influenced by self-efficacy (Lent 2005) and self-efficacy has been shown to be a powerful motivational construct relating to choices in class activities and to persisting in engineering education (Hackett *et al*. 1992).

In addition to motivational factors related to students' perseverance and success in an engineering programme, student learning styles need to be considered in designing a new approach to teaching engineering. Kolb (1976) identified four types of learner: accommodators characterised by doing and feeling; divergers characterised by feeling and watching; assimilators characterised by watching and thinking; convergers characterised by thinking and doing. The population is divided roughly equally amongst these learning types (Philbin *et al*. 1995) although it has been argued that assimilators are best suited to academic careers (Kolb 1976) and thus are most likely to shape the academic world with the adopted learning style favouring assimilators. Cagiltay (2008) found that most of the engineering students he studied were assimilators and thus well suited to the dominant learning style in engineering schools. Honey and Mumford (1992) argued that individuals cycle through doing, feeling, watching and thinking as part of a learning process. The cycle starts by having an experience (doing and feeling), progresses to reviewing the experience (feeling and watching) and then concluding from the experience (watching and thinking) prior to planning the next steps (thinking and doing). The traditional engineering lecture tends to only involve 'watching and thinking' or 'reflective observation' and 'abstract conceptualisation' (Philbin *et al*. 1995), with laboratory classes providing opportunities for 'doing and feeling' or 'active experimentation' and 'concrete experience' (Kolb 1976). However, laboratory classes are expensive and tend to be a vanishing resource in many engineering programmes. Problem-based learning (e.g. Philbin *et al*. 1995) provides opportunities for students to progress around the entire learning cycle through gaining experience of the problem to be solved, reviewing and concluding from the experience in order to plan for the solution. However, problem-based learning tends to be regarded and implemented as a total approach to education and so a switch to this style of teaching the fundamentals of engineering would require a commitment from all of the faculty members of a programme. An alternative is to draw on the common experiences (step 1 in the learning cycle (Honey and Mumford 1992)) of all students for review in class (step 2 in the learning cycle (Honey and Mumford 1992)) leading to the drawing of conclusions in class (step 3 in the learning cycle (Honey and Mumford 1992)) and homework that stimulates the planning of next steps as part of self-study or discovery (step 4 in the learning cycle (Honey and Mumford 1992)). Such an approach when embedded in a conventional course schedule not only provides an opportunity for progression around the learning cycle but also diversifies the teaching styles and thus increases the probability of engaging students with a wide range of dominant learning styles.

Proposed approach

In the preceding section a number of issues have been discussed, including connections to something familiar (Sheppard *et al*. 2009), curricular links to the real world (Koehn 1995), the desirability of thematic coherence (Hulst and van der Jansen 2002), the need to contribute to student self-efficacy especially via mastery and vicarious experiences (Hackett *et al*. 1992), and the value in moving around the learning cycle (Honey and Mumford 1992). They have been related to the need for the principles of engineering to be presented in a context that is familiar to all students in order to enhance the learning, motivation and hence perseverance and success of all students. An approach is proposed here to meet this need, which is evolutionary and not revolutionary. This recognises that instructors are more likely to introduce change that can be integrated within existing course deliveries without approval by committees. Many of the highly desirable changes proposed by others (e.g. Patterson and Johnson 1992, Tryggvason and Apelian 2006, Sheppard *et al*. 2009) require the complete redesign of programmes and their objectives, which implies a level of committee and administrative approval that will always hinder their implementation. In the proposed approach, the focus is on providing relevance to the students' everyday world through the vehicle of exemplars based on familiar, real-life objects and situations used to illustrate engineering principles. The level of idealisation or abstraction is minimised in order not to lose the relevance and context from the students' perspective; since earlier results (Campbell *et al*. 2008) suggest that the level of difficulty has little effect on the value of the example. The choice of examples is critical to both provide the transparent connection to the experiences of all students and to provide the basis for the straightforward implementation of engineering principles. This evolutionary approach to curriculum reform is further enhanced, for ease of implementation, by embedding the exemplars into lesson plans based on the 5Es (Atkin and Karplus 1962), which have been previously used in a Biological Sciences Curriculum Study conducted in the 1980s (Engleman 2001) and is now considered a part of constructivist learning theory. The 5Es are:

- Engage – **to attract and hold fast** [*the students' attention*].
- Explore – **to look into closely, scrutinise, to pry into** [*the topic of the lesson*].
- Explain – **to unfold, to make plain or intelligible** [*the principle underpinning the topic*].
- Elaborate – **to work out in detail** [*an exemplar employing the principle*].
- Evaluate – **to reckon up, ascertain the amount of** [*knowledge and understanding acquired by the students*].

The definition shown in bold is from the Oxford English Dictionary (Little *et al*. 1983), while the italics are added to put the definition into the current framework.

The 5Es provide a framework for utilising everyday engineering examples to progress around the learning cycle proposed by Honey and Mumford (1992). Students can be engaged by a demonstration for an everyday example. Their previous experience of the everyday example can be explored through class discussion of the demonstration and their own recollections. These first two Es provide an opportunity to connect to the students' own experience of the example (step 1 in the learning cycle (Honey and Mumford 1992)). Then the example can be reviewed and explained in the context of the engineering principle being taught (step 2 in the learning cycle (Honey and Mumford 1992)). Conclusions about the example can be drawn (step 3 in the learning cycle (Honey and Mumford 1992)) and used to elaborate a further example or investigate the same example more deeply. Finally, additional examples from real life can be used to allow students to evaluate their learning and plan their next steps in learning about the topic (step 4 in the learning cycle (Honey and Mumford 1992)).

As an exemplar, a series of lesson plans for an introductory (sophomore) course in mechanics of solids has been defined and published (Patterson 2008). Some everyday examples from this series are listed below, with the topic being illustrated shown in italics in parentheses.

- Movement and extension of cables controlling derailleur gears on a bicycle (*displacement and deformation*).
- Stress and strain in the electrical wires and insulation for iPod earphones (*compatibility and equilibrium*).
- Unscrewing of bottle closures (*stress and strain due to applied torque*).
- Bending of skateboard (*bending moments and shear stress diagrams*).
- Loading on basketball goal during a slam dunk (*eccentric loading*).
- Splitting of sausages during cooking (*Two-dimensional stress systems/Mohr's circle of stress*).

The identification of appropriate examples was performed using focus groups consisting of both mechanical engineers and lay individuals, with a disproportionate representation of women drawn from participants in a project on ‘Enhancing diversity in the undergraduate mechanical engineering population through curriculum change’ funded by the National Science Foundation (NSF project no. 0431756). The essential attribute of all examples was that they had to be familiar to all students. For instance, using sailboats to teach vectors might work in Maine but not in the American Midwest, where many students have never seen a sailboat and may panic about not understanding the context and so fail to listen to the mathematics (Rosser 2004). Alternatively, illustrating the kinematics of particles with walnuts falling from trees might work well on a tree-lined rural campus of a land grant university but is irrelevant for an urban, inner city university. This principle of familiarity also applies when evaluating students, since they are more likely to get a test item correct if the context is familiar to them (Linn and Hyde 1989, Chipman *et al.* 1991).

The examples can be broadly classified as relating to childhood experiences, household activities, high school sports and student transport. These classifications evolved rather than being specified at the outset but they do represent a desire to maintain some thematic coherence, so, for example the bicycle appears several times as does basketball. These classifications may also represent the common experiences of the majority of students. There was an additional layer of consideration in designing the real-life examples. After a scenario had been identified and modelled in a manner that made it accessible to students, it was important to pose questions to which it is useful or interesting to know the answer. The perceived usefulness of their learning influences students' motivation (Wigfield and Eccles 2000) and, in the absence of a useful or interesting end-point, there is a risk that the example becomes a tedious intellectual exercise that will not engage all of the students.

Subsequently, an additional series of lessons plans for an introductory (junior level) course in dynamics has been developed (Patterson 2009) and includes the following examples, again with the topic being illustrated given in parentheses:

- Motion of particles during sneezing (kinematics of particles: rectilinear motion).
- Ejection of bread from a two-slice toaster (kinetics of particles: work and energy).
- Motion of a yoyo (kinematics of rigid bodies: angular acceleration and velocity).
- Locking of front bicycle wheel during braking (motion of rigid bodies: forces and acceleration)
- Skateboarding along a path (plane motion of rigid bodies: impulse and momentum).
- Harmonic motion of a hula hoop (mechanical vibrations: free, undamped vibrations).

In the case of dynamics, the course is for third year (juniors) rather than second year (sophomores) of a Bachelor degree programme and so some of the examples towards the end of the course

Table 1. Extract from Patterson (2008) illustrating use of 5Es with a real-life example

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Real Life Examples in Mechanics of Solids

METHOD OF SUPERPOSITION

9. Principle: Eccentric loading

Engage:
Bounce a basketball into class. There are some free preview clips of basketball coaching at http://www.magicfundamentals.com/clips.htm [*color photograph of slamdunk by MSU player*]

Explore:
Discuss the loading on the basketball pole during different types of play, e.g.

- Static compression with low level bending due to offset of backboard and goal;
- Additional low level bending during a goal;
- Dynamic bending when the ball bounces off the backboard from a long shot plus torsion if the shot is wide; and
- High level compression and bending during a slam dunk.

Explain:
Ask the students, working in pairs and sketching, to identify forces and moments acting about the center of the cross-section of the pole that are equivalent to the weight of a player hanging on the rim. [*solution supplied in diagrammatic form*]
Explain that if these forces only produce linear elastic deformation then their effects can be added together, or superimposed. Discuss the principle of superposition.

Elaborate:
For a pole 10 cm square manufactured from aluminum with a 60 cm offset when a player hangs from the front of the ring at an effective distance from the backboard of 50 cm, the maximum tensile stress in the pole occurs on the back of the pole. [*worked solution supplied*]

Evaluate
Ask students to attempt the following examples:

Example 9.1

Calculate the tensile maximum stresses when a 90 kg basketball player hangs from the side of the ring for a goal mounted on a 12 cm square section pole with wall thickness of 3 mm with an offset of 1m from the pole center to ring center. The ring diameter is 42 cm. [*worked solution supplied*]

Example 9.2

Ask students to look for two other examples in their everyday life and explain how the above principles apply to each example.

Note: Comments in italics refer to material removed in the interest of brevity.

involve a stronger connection to professional engineering than the students' everyday experience, although the latter is still present. For example, a robotic violinist (see 'Toyota violin playing robot' on YouTube[3]) is used to transition from playing the violin to industrial robots to elucidate three-dimensional kinematics of rigid bodies.

Each series consists of 12 lesson plans so that they can be easily integrated into a semester-length course. The use of the 5Es within a lesson plan is displayed in Table 1 for the basketball goal example with the illustrations and solutions removed, as explained in the parentheses, to allow the extract to be contained within a single page. Each lesson plan is constructed around an engineering principle or concept and consists of suggestions for engaging students and detailed 'real-life' examples for exploring, explaining and elaborating the engineering concept as well as additional 'real-life' examples for evaluating student understanding.

Experimental evidence

This approach to constructing lesson plans using 'real-life' examples was piloted in a mechanics of solids course that formed part of a previously reported study (Campbell *et al*. 2008). The participating colleges and universities were Johns Hopkins University, California State University, Los Angeles, Smith College, University of Washington, Stevens Institute of Technology, Howard

University and Tuskegee University. The work was conducted using four courses: Freshman Experiences in Mechanical Engineering (33 students); Introduction to Mechanical Design (14 students); Materials Engineering (16 students); Mechanics of Solids (37 students). For most of the courses, a control class was available, which was taught without the 'real-life' examples, often by the same instructor.

Students were asked to assess each example for level of difficulty, overall value, contribution to their learning and participation. They were also asked to assess the course for level of difficulty, degree of interest, participation in learning, increase in their own engagement and improvement in class participation. Control classes of students who were taught by the same instructors in the traditional way without the 'real-life' examples were asked the same questions. In addition, the classes using the 'real-life' examples were asked open-ended questions about whether the 'real-life' examples contributed to their mastery of the subject, course activities that increased their interest in mechanical engineering and course activities that greatly increased their knowledge of a specific course topic. Pre-course, mid-course and post-course interviews were conducted with participating instructors to solicit their views on the impact, if any, of the examples on teaching, unintended outcomes of using the examples, their willingness to use the examples again and any impact on the students of the examples. This study was small, involving 100 students (33 of whom were women) in four different courses, one of which was mechanics of solids. Consequently, the authors did not draw conclusions about the relative effectiveness of the proposed approach in teaching men and women. However, the study did show that the proposed approach has a positive impact on student interest and learning (Campbell *et al*. 2008). Students believed that most of the 'real-life' examples in the study made at least a medium contribution to their understanding and those in the mechanics of solids course, which were the only ones embedded in 5Es lesson plans, were consistently rated as good ($\mu = 3.4$, SD 0.073) on a scale of 1 (= very low) to 5 (= very high). In the study, student ratings of the degree to which a 'real-life' example contributed to their understanding correlated very highly with their rating of its overall value (correlation coefficient, $\rho = 0.77$). Their rating of the degree to which a 'real-life' example contributed to their understanding was also correlated highly with their rating of its positive impact on student participation ($\rho = 0.57$). There was no significant correlation between students' ratings of the difficulty of an example and their ratings of its value, its contribution to their knowledge and its contribution to classroom participation (Campbell *et al*. 2008).

For the mechanics of solids course, students were asked to rate their learning experience for some of the fundamental concepts in the course. For concepts illustrated by 'real-life' examples, significantly more students in the course with the 'real-life' examples rated their learning as high or significant than in the control class (85% vs. 70%, $\chi^2 = 4.08$, $p < 0.05$). There were no significant differences between the ratings from the classes (67% vs. 62%) for concepts that were not illustrated by 'real-life' examples (Campbell *et al*. 2008).

Almost two-thirds (63%) of the students listed activities that increased their knowledge, including the 'real-life' examples; while others commented on the value of laboratory classes, 'real-life' examples and practical applications (Campbell *et al*. 2008). Altogether, 84% of the students listed activities that increased their interest in mechanical engineering and the 'real-life' examples figured prominently in this list (Campbell *et al*. 2008).

While some are suspicious of the value of student ratings of courses, most instructors are concerned about the impact of course changes on the ratings by the students. In the reported study (Campbell *et al*. 2008), students rated teaching effectiveness as significantly higher in the courses with the 'real-life' examples compared to the control classes ($t = 1.4$, $p = 0.05$). The same trend was found in the rating of the overall quality of the course, although at a higher level of significance ($t = 1.54$, $p = 0.03$). Student enthusiasm, engagement and interest were the reasons instructors gave for continuing to use slightly more than half of the examples in the study and all except one of the examples in the mechanics of solids course. In fact, instructors planned to continue to use all of the examples used in the study, with the exception of four that they felt were too time-consuming (Campbell *et al*. 2008). Three of these four were the examples that obtained the lowest ratings from the students, so perhaps either 1) there is a correlation between those examples that can be dovetailed into the delivery of the course with minimum disturbance and those that engage the students and provide maximum benefit to the students or 2) instructor's perception of the example influences the students' opinions.

While there is limited evidence for the efficacy of the proposed approach to teaching engineering, there is a very considerable body of research on context-based teaching of science in high schools (Stinner 1995), which is sometimes referred to as Science-Technology-Society teaching (Aikenhead 1994). A recent review (Bennett *et al*. 2007) of evidence from 17 experimental studies in eight countries concluded that context-based science teaching causes an improvement in the understanding of scientific ideas and increases the positive attitude of men and women to science and also reduces the associated gender differences. Perhaps as importantly, the review concluded that the approach had no drawbacks in the development of an understanding of science. It is reasonable to expect these conclusions to extend to the teaching of engineering in introductory courses at university.

Discussion

While the approach described in the preceding sections can be deployed in all engineering disciplines, it has so far only been possible to implement it in mechanical engineering at a relatively small number of institutions. Hence, the only available study (Campbell *et al*. 2008) has a small sample size and dataset. There is a clear need for more data to confirm the results from the pilot study and also to extend it to include retention, recruitment and gender issues. The former require much longer term studies than have been viable so far. However, the results from the pilot study confirm the conclusions drawn from the literature and are sufficiently positive enough that an NSF extension project is underway to extend the use of everyday examples to illustrate engineering concepts in 30 universities over the next three years. This dissemination process will provide substantial opportunities for collecting additional data.

The conclusions from the pilot study challenge the commonly held belief of faculty members that the difficulty experienced by engineering students is intrinsic to the subject (Sheppard *et al*. 2009) since there was no significant correlation between the students' rating of difficulty and their rating of the value, contribution to their knowledge and contribution to classroom participation of the 'real-life' examples (Campbell *et al*. 2008). The data from the pilot study and the literature on student success suggest that the learning of engineering fundamentals can be motivated more by interest and connections than by fear of failure due to the difficulty of the subject, providing that an appropriate approach is taken to teaching. This would appear to be consistent with the concept that knowledge consists of a network of connections or pathways linking structures of information, which are continuingly rearranged and become increasing well-trodden as one learns (Greeno *et al*. 1996, Yeun 2004).

Any committed instructor can develop appropriate examples that draw on the everyday experiences of their students and which provide an interesting or useful insight into the scenario being analysed. The evidence suggests that instructors who engage in such activity will be rewarded by students who are more engaged, more motivated and more likely to give the instructor and the course a high rating. Thus, the impact of this mutual exploration of the subject is likely to be higher retention rates. Studies at Carnegie Mellon in computer science (Margolis and Fisher 2002) and at Drexel in engineering (Fromm 2003) have also shown that the integration of appropriate applications into the teaching of engineering fundamentals increases the recruitment and retention of women. While more recently, Du and Kolmos (2009) have shown that 'contextualised content' in engineering programmes will improve recruitment of women as well as increasing the level of appreciation of learning. Thus, the approach presented here would be expected to have a similar impact and thus lead to a greater proportion of the population gaining a university-level education in engineering. Such an outcome is likely to lead to more sustainable engineering solutions to providing the services and products expected by society.

It is suggested that introducing everyday examples into engineering teaching is an incremental change that every engineering instructor could achieve using the 5E lesson plan and that would have an impact. To assist those who wish to create their own 'real-life' examples, the simple rule is that they must relate to the everyday experience of a diverse student population. However, in more detail, examples should:

(a) be familiar to diverse groups of students;
(b) pose questions to which to it is useful or interesting to know the answer or be transparently relevant to the challenges facing society;
(c) contain a low level of abstraction in order to make a clear connection to reality;
(d) provide a basis for the straightforward implementation of engineering principles;
(e) have some thematic coherence;
(f) together form a wide range of artefacts.

It is clear that there are some tensions at an increasing level between a) and b), between c) and d) and between e) and f). However, the authors have found that this tension helps to stimulate the creativity needed to generate a good set of 'real-life' examples.

For those lacking the time, creativity or inclination to develop their own examples, then the sets of lesson plans (Patterson 2008, 2009, 2010) being developed by the authors offer an alternative route, which it is hoped will be augmented by others across the engineering disciplines, e.g. ENGAGE (2010). These lesson plans can be employed to guide the delivery of an entire lesson or a part of a lesson or could be used by students for private study.

Conclusions

The importance of context in exemplars has been discussed with the aim of enhancing student success across a student population with increased gender diversity. Student success is a multiplicative function of ability and motivation (Pinder 1984, Chan *et al*. 1998) and the latter is improved by curriculum links to the outside world (Koehn 1995) drawn from the students' everyday experience, i.e. 'real life'. Academic procrastination is reduced and sometimes alleviated by thematic coherence (Hulst and van der Jansen 2002) and so the repeated appearance of familiar objects in sets of exemplars is desirable, such as the bicycle (Patterson and Johnson 1992). A belief in one's own ability is also important for success (Marra *et al*. 2009) and mastery experiences for men are important (Zeldin and Pajares 2000), whereas social persuasion (Bandura 1997, Zeldin and Pajares 2000) and vicarious experiences (Zeldin and Pajares 2000) are important for women. These gender differences in self-efficacy are likely to have a substantial effect on retention and success of women in engineering because teaching of most of the engineering fundamentals is focused on mastery exercises designed around highly abstract problems with little or no connection to the everyday experiences of students. These mastery exercises heavily favour the self-efficacy beliefs of men and the lack of connection to observed experiences of women does not contribute to their self-efficacy.

Context has been used in both its modern and old-fashioned meanings, i.e. 'surrounding conditions' and 'a construct of speech'. The former implies that it is important to teach engineering by reference to the everyday of experience of the students, while the latter has been used to describe an idiom of models and analogies that renders engineering inaccessible to many students. The tendency for teaching in engineering programmes to favour the learning styles of assimilators, characterized by watching and thinking or reflective observation and abstract conceptualisation (Kolb 1976), has also been discussed. The use of examples from the everyday experience of students within lessons plans based on the 5Es (engage; explore; explain; elaborate; evaluate) is proposed to resolve these issues. The use of everyday examples to engage students provides the opportunity to build on experiences that most students will have already had outside of the classroom, to review those experiences through exploration during the lesson and to conclude from those experiences through elaboration in the lesson and the student's own evaluation of their understanding in homework. The evaluation step can also stimulate planned self-exploration so that the complete process resonates with the learning cycle identified by Honey and Mumford (1992).

Some of the underlying principles for these concepts have been confirmed by studies in teaching science (Bennett *et al*. 2007) and by data from an earlier study (Campbell *et al*. 2008) of teaching engineering with exemplars related to everyday experiences of students. Student evaluation of their learning in these courses was strongly correlated with their interest and their participation but was not related to course difficulty, which confirms the importance of motivation (Campbell *et al*. 2008). Students who were more interested in the course also believed that they learned more and felt that they, and others, participated more in the course (Campbell *et al*. 2008). Additional data from long-term studies are required. However, it is clear that 'real-life' examples can increase student interest, motivation and participation and hence make a significant difference to the teaching of fundamental concepts of engineering. The introduction of such exemplars requires only an incremental change in teaching methodology and the 5Es lessons plan provides an easy route for implementation. Thus, the proposed methodology can be implemented by individual instructors without the need for approval by committees or administrators, but with the benefit of providing conditions that are more conducive to learning. This will encourage better motivation and engagement for all students, since if a teaching technique is good it is better for everyone regardless of learning style (Pashler 2010).

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Notes

1. Amount of productive land and coastal marine environment required for food, water, housing, energy, transport, commerce and waste management (Wilson 2001).
2. A mechanical damper that resists motion via viscous friction generating a force proportional to velocity.
3. http://www.youtube.com/watch?v=EzjkBwZtxp4 [Accessed April 2011].

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