The Relevance of Relevance in Exemplars for Dynamics and Mechanics

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Abstract

Research has shown that students have a preference for teaching methods that include discussion and problem-solving, working in teams and outside speakers and, or visual presentations. It has also been shown that student success is a multiplicative function of ability and motivation with the latter connected to good 'achievement striving' and 'situational expectations'. Motivation is significantly enhanced by guest speakers, field trips, student clubs and relevant/appealing applications. Traditional examples employed to illustrate basic engineering concepts often appear irrelevant and abstract to students, particular those from under-represented groups in engineering (women and minorities). This lack of perceived relevance to life as they have experienced can be very discouraging to students leading to a lack of interest and motivation causing poor recruitment, performance, and retention. We have developed a set of lesson plans for Sophomore level Mechanics of Solids and another set is under development for Junior level Dynamics which provide real-life examples utilizing common themes with which students are familiar. Thematic coherence as been shown to promote good academic progress and to counter academic procrastination, an inverse from of motivation. The lesson plans are based on the 5Es: Engage; Explore; Explain; Elaborate and Evaluate which was successful used in the Biological Sciences Curriculum Study in the 1980s. Examples involving bicycles, iPods and skateboards will be used to illustrate how relevance to student life and interests can provide interest, motivation and attention to study as demonstrated by student achievement and attitude data obtained from pilot teaching using the Real Life Examples in Mechanics of Solids.

Introduction

The problems of recruitment and retention of under-represented minorities in engineering are well documented For instance, a recent report from the National Academy of Engineering [1] collated data which showed that, while the proportion of African Americans, Hispanics and Native Americans enrolled in degree-granting institutions in the US in 2004 was approximately equal to that in the population, the proportion enrolled in bachelor's degrees in engineering were only 0.41, 0.52 and 0.6 respectively of the proportion in the population; while women represent only 20.5% of the engineering bachelor's degree enrollment and 50.7% of the population. In this paper it is surmised that the traditional approach to teaching mechanical engineering naturally favors the dominant consumers of bachelor degree programs, namely white men; and in order to create a more diverse student body and hence profession, new ways of presenting the subject need to be implemented. A more diverse profession is essential for facing the challenges and uncertainties that lie in the future [2]. It has already been proposed [1] that advertising engineering as requiring a high level of mathematics and physics is counter-productive and instead the focus needs to be messages such as 'engineers make a world of difference' and 'engineering is essential to our health, happiness and safety'. While Sheppard et al [3] 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 pro-*

fessional 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 to connect traditional engineering science subjects, which are usually taught in the context of idealized engineering applications that are typically biased towards white males, to real-life examples that form part of the everyday experiences of all students.

Background

Koehn [4] has shown that students rank: combined lecture/discussion/problem-solving and opportunity for student input; working in teams and group interactions; outside speakers and/or visual presentations; computer assignments and field trips most highly amongst fourteen teaching methodologies. Separately, student success has been found to be a multiplicative function of ability and motivation [5, 6] 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 [7]. These factors can be enhanced by improving curricula links to the outside or real world such as the guest speakers and field trips identified by Koehn [4] and by utilizing relevant exemplars, i.e. relevant to the students' everyday experience.

Perhaps the inverse of motivation is procrastination which is defined as *'postponing a task to the extent of experiencing subjective discomfort'*. Academic procrastination is determined by a student's personality, time management skills and motivation but also by situational factors such as scheduling of courses [8]. The latter implies that, for good progress, competition between courses should be reduced and thematic coherence should be promoted [9]. At the University of Sheffield in the 1990s [10] 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. In the first year of the program, the bicycle was used as an over-arching theme to provide coherence since nearly every student has a bicycle either on campus or at home.

In this study the focus has been on providing relevance to the real or everyday world through the vehicle of exemplars or applications used to illustrate engineering principles. Examples from the real world and more specifically everyday life have been idealized to provide the basis for the straightforward implementation of engineering principles. This is an evolutionary rather revolutionary approach to curriculum reform which is simple to implement. This approach has been further enhanced by embedding the exemplars into lesson plans based on the 5Es [11] which has been previously used in a Biological Sciences Curriculum Study conducted in the 1980s [12] 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, scrutinize, 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 in bold is from the Oxford English Dictionary [13] while the italics are added to put the definition into the current context.

Real-Life Examples

Space limitations and layout preclude the inclusion of any full lesson plans however an example from the sophomore Mechanics of Solids series is available on-line [www.engineeringexamples.org] and the whole set has been published [14]. Real life examples from this set include, amongst others:

- derailleur gears on a bicycle (displacement and deformation);
- iPod cables (compatibility and equilibrium);
- bottle closures (stress and strain due to applied torque):
- skateboarding (bending moments and shear stress diagrams);
- basketball goal (eccentric loading); and
- sausages cooking (Mohr's circle of stress).

The topic being illustrated is given in italics. The series for junior Dynamics includes examples based on:

- sneezing (kinematics of particles);
- a two-slice toaster (kinetics of particles: work and energy);
- a leaf blower(systems of particles: steady stream of particles); and
- pedaling a bicycle (kinematics of rigid bodies).

The use of the 5Es is illustrated in the box below for the basketball goal example with the illustration and solutions removed to conserve space as explained in the parentheses.

<u>*Real Life Examples in Mechanics of Solids*</u>

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.

o Static compression with low level bending due to offset of backboard and goal;
o Additional low level bending during a goal;
o Dynamic bending when the ball bounces off the backboard from a long shot plus torsion if the shot is wide; and
o 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 10cm square manufactured from aluminum with a 60cm offset when a player hangs from the front of the ring at an effective distance from the backboard of 50cm, 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:

<u>*Example 9.1*</u>

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

<u>*Example 9.2*</u>

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

This approach to constructing lesson plans using real-life examples was evaluated in a pilot study during the 2006-07 academic year along with similar concepts in fluid mechanics and design. The participating colleges and universities were Johns Hopkins University; California State University, Los Angles; Michigan State University; Smith College; University of Washington; Stevens Institute of Technology; Howard University; and Tuskegee University. The evaluation was conducted using four courses:

- Freshman Experiences in Mechanical Engineering (Fall, 2006)
- Introduction to Mechanical Design (Fall, 2006)
- Materials Engineering (Spring, 2007)
- Mechanics of Solids (Fall, 2007, Spring, 2007)

Students were asked to assess each application for level of difficulty and overall value, contribution to their learning and participation. They were also asked to assess the course for level of difficulty, interest, learning, participation, and class participation. A control class of students who were taught in the traditional way without the new lesson plans was asked the same questions. In addition, the classes using the lesson plans 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. The detailed results have been presented elsewhere [16]. In general, the evaluation of the new lesson plans was positive. Students believed that, most of the applications made at least a medium contribution to their understanding and the three best 'real life' examples were rated as being particularly effective in contributing to their understanding of basic engineering principles. Each of these three highly rated examples was used in a different course. 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 (.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 (.57). There were no significant correlations 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.

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. Only 10% of students believed that there were topics in their courses that did not contribute to their mastery of the content. The real life examples appear to have an impact on student interest as well. Eighty-four percent of the students listed activities that increased their interest in mechanical engineering and the real-life examples figured predominantly in this list.

Conclusions

The importance of relevance in exemplars has been discussed in the context of enhancing student success across a diverse student population. Student success is a multiplicative function of ability and motivation and the latter is improved by curriculum links to the outside world which can be provided by examples drawn from the students' everyday experience, i.e. 'real life'. Academic procrastination is reduced and sometimes alleviated by thematic coherence and so the repeated appearance of familiar objects in sets of exemplars across mechanics and dynamics is desirable, such as the bicycle and iPod.

These concepts were confirmed by a pilot deployment of the new lesson plans with the exemplars embedded. 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. 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. This same relationship was observed for the 'real-life' examples that were introduced to stimulate interest and increase motivation. Student motivation, interest, and learning are very tightly bound together and the latter two were found to be tied to participation. Real life exemplars can increase student interest, motivation and participation and hence make a real difference to the teaching of fundamental concepts of mechanical engineering.

Acknowledgements

The authors gratefully acknowledge the support of the National Science Foundation for its funding of this work through project #0431756 entitled: "Enhancing Diversity in the Undergraduate Mechanical Engineering Population through Curriculum Change".

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