Increasing pass rates in introductory mechanics courses

Alan Jowitt.
AUT University
Corresponding Author Email: ajowitt@aut.ac.nz

Structured Abstract

BACKGROUND

Low pass rates in introductory mechanics courses are commonly observed in universities throughout Australasia and elsewhere. In the author's experience pass rates rise when the number of assignments rises. Unfortunately, with increasing class size, more assignments cause marking loads to become unmanageable.

PURPOSE

A teaching methodology that would encourage students to accept responsibility for, and to become involved in their studies was sought. The goal was to develop a system that would stimulate students to experience deep learning and to do more work, at the same time as reducing assessment load.

APPROACH

A system was developed that required all students to author questions and provide worked solutions, to be submitted in hard copy, the do-it-yourself (DIY) assignment. The lecturer chose one submission and wrote solutions that showed four lines of working for each line that was required for that solution. Only one of the given lines was correct, with subtle errors in the remaining three lines.

The chosen problem and solution with four options for each line of working was posted online in multiple choice question (MCQ) format. For students to answer the MCQs they would have to carefully consider each line of working in order to decide on which answer to choose, thereby experiencing deeper learning than would take place in attempting simpler MCQ assessments.

With automated marking available for MCQ assignments it was possible for the lecturer to set any number of assignments with no increase (in fact a substantial decrease) in marking load.

The concepts of student-authored problems and online assessment are not new. What is believed to be unique in this paper is the provision of optional lines of working for students to analyse in deciding upon their answers.

OUTCOMES

In a strength of materials course, the above methodology was employed for problems in Macaulay's method. The balance of the course did not employ the methodology. In the final exam, the average mark for the Macaulay's method question was 65%, while the average mark for the remaining questions was 60% or lower.

Students were surveyed to determine their experience of the DIY methodology. The overwhelming indications were that students felt they learned more from the DIY assignment than from other types, became engaged in the work, and appreciated instant availability of marks upon submission.

CONCLUSIONS

Observations made to date indicate that the DIY assignment has potential to improve student learning and exam pass rates. Acknowledging that there is risk in making abrupt changes in teaching and assessment methods, it is proposed to structure courses so that DIY assignments comprise (say) 20% of the total assessment, then to increase that percentage as the methodology is seen to produce higher marks in formal assessments.

KEYWORDS

Introductory mechanics, pass rates, teaching methodology, engaged, learning.

Introduction

Motivation

The motivation for this article is to address means of increasing pass rates in introductory mechanics courses. High pass rates are not in themselves indicators of good teaching practise or student learning because of the variables in student cohort, course delivery and assessment methods. However if a rising trend can be obtained in pass rates while consistency in delivery and assessment is maintained then it may be suggested that teaching and learning are improving.

In New Zealand there is, distastefully, a commercial reason for achieving higher pass rates in university courses. The Tertiary Education Commission (TEC) develops policy for funding Tertiary Education Providers (TEPs). That funding has a Student Achievement Component (SAC) such that a course is fully funded in a given year only if the pass rate the previous year was 50% of enrolled students or higher (TEC, 2013).

The TEC has indicated that the SAC threshold for continued, full funding to TEPs is to increase by a nominal 5% per annum. If a threshold of 50% becomes 55% the required increase in numbers of students who pass is in fact 10%. That is a significant demand, particularly where present pass rates are marginal.

It is the author's conviction that students cannot succeed in a mechanical engineering course if an understanding of introductory mechanics is not achieved. Hence it is suggested that a qualification in mechanical engineering cannot be completed unless a pass in introductory mechanics is gained. This suggestion is reinforced by a stipulation that mechanics courses are prerequisites for entry to subsequent courses.

The present author has observed that pass rates are higher when the number of assessments set during the course is increased. Increasing assessment has the undesirable and obvious consequence of increasing lecturer workload.

Multiple choice questions (MCQs)

Recent developments in automated marking of MCQ assignments make their use particularly attractive to lectures seeking to optimise use of their own time, whilst simultaneously enabling students to increase their engagement with the subject at hand. It is not technology that causes learning, but the instructional method, (pedagogical approach, learning design) (Draper, 2009). Shallow learning is characterized by retention of true-false items that are either disconnected or linked in only one way for one use. Deep learning is characterized by learning multiple relationships between items that can support multiple uses. Draper claims that appropriately designed MCQs can stimulate the learner into making more links than would result from poorly designed MCQs, thus facilitating deep learning.

The use of MCQs as a valid assessment tool is contentious. It is not proposed to contest the notion that MCQs comprising a simple memory test do not promote deep learning.

Instead it is proposed that student authoring of MCQs which require some calculation to arrive at the correct answer do indeed entail some high level cognitive processes which are likely to result in deep, rather than surface learning (Mayer, 2002).

Learning and teaching strategies are often viewed in the light of Bloom's taxonomy (knowledge, comprehension, application, analysis, synthesis and evaluation) of 1956. The taxonomy was revised in 2002 and is now portrayed as six cognitive process categories: remembering, understanding, applying, analysing, evaluating and creating.

Mayer suggests that creating requires taking the first five elements and putting them together to form a new pattern or structure. The process comprises three phases: problem representation, solution planning, and solution execution. The phases can be represented by

the cognitive processes, generating (hypothesising), planning (designing) and producing (constructing). The transfer of learning to real applications is facilitated through creating (Mayer, 2002).

Meaningful assessment tasks should not be confined to recognising and recalling, but should require use of all the foregoing cognitive processes. In composing their own MCQs students are required to function at the creative level, and to contemplate potential errors that might arise in attempting solutions. The latter requires evaluative and analytical functions.

A development of the learner authored assessment, described by Fellenz, is the multiple choice item development assignment (MCIDA) (Fellenz, 2004). The MCIDA requires students to consider course material and to synthesise problems and solutions, necessitating use of higher cognitive processes.

Fellenz found that students invested considerable time in MCIDAs and consequently awarded 20% of the overall course assessment to MCIDAs. A checklist is provided with each MCIDA to help students to decide whether the requirements of the assignment are met. Following submission feedback is given in the form of a standard sheet, addressing the essential aspects of formulating the MCIDA.

Students are asked to identify the cognitive level of the educational objective each MCIDA sets out to test. It is claimed that the process engages students in meta-learning by requiring reflection on the nature of the learning, and on the cognitive skills required to answer the questions.

MCIDAs appear to increase the time students spend on learning course content, and cause them to feel some ownership of the assessment of their learning. Increased reflection of learning approaches occurred also. Students engage with subject matter at high cognitive levels. When setting MCIDAs as group assignments the lecturer may observe dual benefits in encouraging learner collaboration and reducing workload in giving feedback.

Fellenz requires students to justify correct and incorrect answers, thus requiring them to make explicit their understanding of the complexities of the subject matter.

David Nicol explores further the use of MCQs and MCIDAs and maintains that the value of MCQs depends on how they are constructed and that they can be used to evaluate learning at higher cognitive levels (Nicol, 2007).

A case study considered a Fundamentals of Human Physiology course in which students who passed three written assignments failed the final exam. Part of the problem was that the feedback from conventional assignments was provided too late to enable students to reflect constructively on assignments submitted earlier. MCQs with automated marking provide instant feedback and enable the lecturer to rapidly determine which material causes difficulty.

A refinement of MCQ tests is confidence based marking (CBM). CBM requires students to rate their confidence level (low, medium or high) in the answer submitted. Wrong answers attract a penalty, the magnitude of which is related to confidence level. In addition to selecting the perceived correct choice of answer to an MCQ, students were required to specify a confidence level for their selected answer. For a wrong answer for which the confidence level was high, the penalty is six marks, and 2 marks for medium confidence level. The mark awarded for a correct answer is one for low, two for medium and three for high confidence. It is claimed that learners are forced to reflect on the soundness of their answers and to assess their reasoning.

In a first-year mechanics course at the University of Strathclyde, UK, non-completion rates have fallen from 20% to 3%. Nicol claims that increase in completion rate to be a result of MCQ testing integrated with an electronic voting systems (EVS). Students take an online MCQ assessment before a classroom session in which EVS is used to evaluate understanding of concepts, and to promote discussion of problem areas.

The standard lecture format, associated with tutorials and laboratory sessions, was replaced by a series of two-hour sessions characterised by short presentations, problem solving and demonstrations, integrated with MCQ tests, EVS and CBM. CBM causes students to reflect on whether there is good justification for answers presented and results in meta-cognitive thinking.

For the lecturer, the EVS rapidly identifies topics with which students experience difficulty, enabling the lecturer to respond appropriately. Further, the EVS can indicate when the difficulties have been overcome.

The new lecture format provides opportunities for self assessment and reflection. Lecturers give feedback during the class in the form of answers to questions asked. A component of CBM when conducted during the interactive class sessions is that students discuss among themselves reasons why answers proposed are right or wrong, and students with correct answers are given the task of convincing their peers of their reasoning.

In EVS classes the difficulty of questions increases progressively and the focus is on learning goals rather than performance goals. There is a continuous cycle of testing, retesting and feedback. The lecturer becomes instantly aware of concepts with which students experience difficulties. Attendance is greater than in old lectures, and retention rates are increased.

Nicol employed MCIDAs in his teaching strategy, and observed that control of the assignment is taken from the lecturer and placed in the hands of students. As an incentive to participate in the MCIDA process, students were advised that some of the questions they had written would be incorporated in final examinations.

Nicol claimed that the MCIDAs, being completely learner centred, engaged students deeply in their work and contributed to self-regulatory skills. Feedback from students strongly indicated that a deep understanding of course material was acquired, and that the exercise was a very powerful learning experience.

The practise of learners authoring test questions promotes student autonomy and self-monitoring (Draper, 2009).

Research questions

This undertaking sought to answer two questions:

Would students engage with self-authored assignments more deeply than with prescribed assignments?

Would their exam performance be enhanced as a result of undertaking self-authored assignments?

Methodology

For the purposes of a pilot study, students enrolled in the Strength of Materials II course at AUT University School of Engineering were required to complete two DIY assignments. The course topics included complex stresses and strains (analytical and Mohr's circle approaches), thick and thin walled cylinders, beam deflections (by integration and moment area methods, and Macaulay's method), lateral and volumetric strain, and strain gauging.

The first DIY assignment was relatively simple, involving beam reactions and bending moments. The second was an extension of the first and necessitated analysis of beam deflection and slope by Macaulay's method. After the assignments were completed the participants were surveyed to establish their perceptions of their own engagement and learning that occurred during the DIY assignments

On completion of the final examination, the average mark obtained for each question was found.

The DIY assignments undertaken

For the first assignment, students formulated a beam reactions problem, for which the number and types (point, uniformly distributed and couple) of load were specified. The requirements were for each student to define the location and magnitude of each load, the beam length, and to calculate left and right reactions. Bending moments at four locations along the beam were calculated also.

A further requirement was to submit four answers for each unknown in multiple choice format. Of the four answers one was to be correct while the others were to be subtly incorrect, perhaps expressed in the wrong units or having the decimal point in the wrong place.

Each participant handed in a completed, hand written assignment. The lecturer selected one and set it as an online assignment for the class.

The second assignment, an extension of the first, required maximum deflection, and location of maximum deflection, to be found by Macaulay's method. The hand written submissions included four choices for each of the main steps in solving the problem. One submission was chosen by the lecturer and posted online, and the class completed the multiple choice exercise online.

Online presentation of multiple choice solutions

A point of difference between assignments found in the literature and those developed by the current author lies in the presentation of the multiple choices offered for the solutions. Common practice in MCQ assessment is to offer the student four (say) options a, b, c and d from which the student makes a choice.

An example of the options presented in this study is shown in

Table 1. In addition to options a, b, c and d, a line of working is given for each option. Naturally only one line is correct – the student has the opportunity to study each line in detail and to compare with his or her own reckoning.

Table 1: Multiple choice solutions for DIY assignment two, left reaction

Left reaction

a.	$R_L = \frac{(10 \times 10^3 \times 2) - (15 \times 10^3 \times 5) + (5 \times 10^3 \times 4 \times 2)}{10} = -1.5\ kN$
b.	$R_L = \frac{-(10 \times 10^3 \times 2) + (15 \times 10^3 \times 6) + (5 \times 10^3 \times 4 \times 2)}{10} = 11\ kN$
c.	$R_L = \frac{(10 \times 10^3 \times 2) + (15 \times 10^3 \times 4) + (5 \times 10^3 \times 4 \times 8)}{10} = 24\ kN$
d.	$R_L = \frac{-(10 \times 10^3 \times 2) - (15 \times 10^3 \times 5) + (5 \times 10^3 \times 4 \times 2)}{10} = -5.5\ kN$

Survey

At the conclusion of both assignments students were surveyed so as to ascertain their feelings about the DIY assignments. The class was presented with the 12 statements shown in Table 2, to which they responded on a standard Likert scale. Responses ranged from strongly disagree (1), disagree (2), neither agree nor disagree (3), agree (4) to strongly agree (5).

Table 2: Survey statements and summary of responses

Statement	Mean score	SD
The do it yourself style of assignment caused me to feel engaged in the work	4.4	0.52
I felt I learned about the topic by composing the question and solution	4.6	0.5
I prefer the type of assignment in which questions are written for me	3.9	1
I enjoyed the DIY assignments	4.2	0.6
It was helpful to see my result immediately	4.5	0.71
I was more motivated in doing DIY than in conventional assignments	3.9	0.7
I prefer multi choice assignments to those requiring full solutions	3.9	0.6
I prefer carrying out assignments online	3.4	1.3
I guessed the answers	1.6	1.3
I calculated answers to questions (or analysed the given calculations)	4.6	0.5
I thought the DIY assignments were unreasonably challenging	2.4	1
I would like to see more of these assignments in future	3.9	1

Results

Average scores for the five types of exam question are shown in Table 3:

Table 3: Mean scores for exam questions

Question type	Mean score
Beam deflections and slope using Macaulays method	65%
Beam deflections and slope using moment area method	42.5%
Complex stresses	45%
Strain gauging and strain energy	60%
Thick walled cylinders, lateral and volumetric strain	42%

Mean scores and standard deviations (SD), shown in Table 3, for the survey responses were calculated according to the weightings in Table 4.

Table 4: Response weightings

Response	Score
Strongly agree	5
Agree	4
Neither agree nor disagree	3
Disagree	2
Strongly disagree	1

Discussion

Exam results

The exam scores by question type given in Table 3 show that the highest mean score occurred in the question type for which DIY assignments were set. Assignments for the other question types were set in the conventional manner.

That result should be viewed in the context of relative degree of difficulty of the topics in the strength of materials course. The Macaulay's method problems are the only ones requiring integration for their solutions. Other types of problems (thick cylinder, complex stresses and strains, strain energy) can be solved by graphical means, or by application of formulae with some degree of problem synthesis. Further, the 65% mean score is actually 8.3% higher than the next highest of 60%.

Whilst it is unrealistic to make claims about the methodology based on results for a single question in a single examination, it is argued that the process of completing DIY assignments contributed significantly to student engagement and thus learning.

Survey results

A risk of using simple MCQs as a primary assessment tool is that students do not necessarily engage in any high level cognitive processes and may resort to guessing responses. The requirement for students to compose their own questions and submit solutions is seen as a means to draw students away from blindly tackling MCQ assessments and to lure them into creative, high-level thinking.

Survey responses in Table 2 strongly indicate that students were engaged in the work and felt they learned about the subject in the process of authoring questions. A particularly pleasing outcome was that a significant majority students calculated, rather than guessed, answers to the MCQs.

An expected outcome was that students found it helpful to see their results immediately upon submission of their MCQ answers. That aspect was valuable to the lecturer also.

A particularly pleasing result was that a significant majority of students chose their responses to the MCQs based on calculation, rather than on guesswork.

A slim minority indicated that they found DIY the assignments unreasonably challenging. From that it may be inferred that the assignments posed a significant challenge to students, which is considered highly desirable.

Although many students preferred assignments which are written for them, that sentiment was outweighed (4.2 to 3.9) by the assertion that they enjoyed the DIY assignments. Preferences for MCQs and for completing assignments online were clearly indicated.

Students generally experienced higher levels of motivation in formulating DIY assignments than when completing assignments written for them, and clearly signaled that they would like to see more DIY exercises in the future.

Lecturer's perspective

Considerable time was spent in preparing the DIY assignments, particularly in writing solutions with four alternative lines of working for each step. That investment in time was repaid several times over in that marking was automated. The payback increases as class size increases.

Less obvious time savings occurred in eliminating the requirements to organise hard copy assignments to distribute, and to hand back marked work. Further time saving occurred because no students challenged their marks.

Conclusion

A solitary exam question is not a sufficient basis upon which to form far reaching conclusions. Nevertheless it was encouraging to observe that candidates achieved the highest score for the most difficult question in the exam. It is suggested here that increased motivation and engagement experienced by students in formulating the DIY assignments contributed significantly to their success in the associated exam question.

The value of causing students to engage in high level cognitive processes is beyond dispute. What is yet to be established is whether the DIY approach is sustainable (because of time constraints) throughout an entire course of study.

It is the author's intention, in future work, to gradually increase the DIY proportion of course work assigned to students and to evaluate whether the technique has enduring appeal to students.

References

Draper, S. W. (2009). Catalytic assessment: understanding how MCQs and EVS can foster deep learning [Article]. *British Journal of Educational Technology, 40*(2), 285-293. doi:10.1111/j.1467-8535.2008.00920.x

Fellenz, M. R. (2004). Using assessment to support higher level learning: the multiple choice item development assignment [Article]. *Assessment & Evaluation in Higher Education, 29*(6), 703-719.

Mayer, R. E. (2002). Rote Versus Meaningful Learning. *Theory Into Practice, 41*(4), 226-232. doi:10.1207/s15430421tip4104_4

Nicol, D. (2007). E-assessment by design: using multiple-choice tests to good effect. *Journal of Further and Higher Education, 31*(1), 53-64. doi:10.1080/03098770601167922

TEC. (2013). *Deatails for the SAC funded sector*. Retrieved 24 August, 2014, from http://www.tec.govt.nz/Funding/Policies-and-processes/Performance-linked-funding/Details-for-TEOs/