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Interactive Learning in a Level 1 Module

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Abstract

Changes were made to the teaching method and examination paper for a Level 1 Mechanics module taken by a cohort of physics students with the aim of encouraging deep learning. The co-operative learning approach of Johnson et al (1991) was used to pose conceptual questions for interactive discussion. Quantitative and qualitative methods were used to evaluate the effect of the change on student learning. Analysis of the quantitative data showed that there was no discernible overall development of deep learning. However, analysis of the qualitative data showed that experience of the module by both students and lecturer had been greatly improved by the changes.

Introduction

> Through interactions with our social and physical worlds, humans learn to see others, themselves and their physical surroundings in new ways. When interactions do not occur, learning is inhibited. (Roth *et al*, 1999)

We build up our picture of the world through everyday events and we constantly re-adjust our picture in the light of new knowledge and experiences. This process is not instantaneous and it benefits from the opportunity for discussion and debate with others.

In universities the formal lecture is usually central to the teaching of science and engineering, supported by tutorial and laboratory classes and, in later years, student projects. In this environment the opportunities for discussion are often restricted to the 'supporting' activities and generally have to be student initiated. This can create a number of problems for both lecturer and students: the lecturer may be unaware of difficulties that students are having, and students are not able to discuss those difficulties.

In a world where workplace needs are rapidly changing, transferable skills are essential. One of these is the ability to learn without the benefit of formal teaching. Also, in the workplace, 'learning' is more than the memorisation of facts and figures. It involves true internalisation of information to create a more complete picture. This is a *deep learning approach*. Added to the limitations of the formal lecture, the primary assessment method of unseen written examinations often explicitly requires little more than the detailed and accurate reproduction of knowledge and ideas (Black, 1997). It is known that this tends to promote only short-term acquisition of facts and formulae. This is a *surface learning approach*. We wanted to investigate how learning might be improved by emphasising the deeper, more conceptual, aspects of the subject and encouraging discussion and debate during lectures at the time when initial difficulties arise. In this way we hoped to improve both students' understanding of the subject and their ability to learn.

We do not all learn the same way. Preferred learning styles have been categorised into four different types (Kolb, 1983). Each style is dependent upon how we prefer to perceive and then process information. The preferred learning styles may be characterised by questions: 'What?' (assimilators), 'What if?' (accommodators)', 'How?' (convergers) and 'Why?' (divergers). Formal lectures tend only to satisfy the 'What?' question and so only match one learning style. The experiential learning model

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of Kolb suggests that growth and development occur by moving around all four learning styles (the *learning cycle*). We felt that a more interactive teaching style would enable a wider range of preferred learning styles to be accommodated, creating a better experience for students who were not assimilators. This was supported by the knowledge that, until recently, it was thought that emotion (affective) skills played no part in cognitive skill development but it is now recognised that 'attitude' is also important in learning and development (Goleman, 1996).

The New Style of Teaching

The new teaching style was used in the 1998/99 academic year for students on a Level 1 Mechanics module, which ran for 12 weeks in Semester 1. The module was one of six running in that semester. Each week the students attended a double lecture (2×50 minutes with a 10 minute break), and in alternate weeks they attended a 50-minute problem-solving class. We chose the informal cooperative learning approach (Johnson *et al*, 1991) to initiate class discussion. With informal co-operative learning, the lecture is broken up by periods of active student participation. Typically, the lecturer presents material for 15 minutes, and then there is an activity requiring class participation for 5 minutes. For this module, the activity was a *Class Question* that developed conceptual understanding of the current topic. Apart from any other benefits the activity provided a natural break within the lecture, limiting the length of time for which students were required to concentrate

Additionally, concept questions were included on the sheets used in the problem-solving classes and particular care was taken over the choice of numerical problems, so that they required an understanding of the basic concepts in order to correctly formulate the solution, as opposed to just the direct application of simple formulae.

The assessment methodology of the module was already defined. The majority of the module mark was derived from a 1½ hour formal examination and there was a small coursework element. The examination paper consisted of a compulsory section of short questions and a choice of two from four long questions. In setting the examination paper, care was again taken to probe conceptual understanding of the subject.

The printed lecture notes from the previous year's (1997/98) delivery of the module were revised. It was decided not to make major changes to the syllabus content but to take the time that had previously been used for worked examples in class and use it for the Class Questions.

Before each lecture we met with suggestions for amendments and additions to the notes and ideas for questions. Sources used included the course text (Fishbane *et al*, 1993), and a conceptual physics text (Hewitt, 1998). We tried to identify examples that would be familiar to the students in their everyday lives to help them link theory and practice. The proposed changes to the lecture material were then discussed with the lecturer and copies of the new lecture slides made for the students. In their copies: (i) some equations, or parts of equations, were incomplete, and (ii) no references were made to the Class Questions. Omission (i) was to try and keep student attention, and also allow 'ownership' of the printed notes. The benefit of printed notes was that students were able to listen to and think about the material being presented. Omission of reference to the Class Questions was so that students would neither be distracted by the possibility of a question, nor be thinking about its content in advance.

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In the first lecture we gave a presentation to the students explaining that the module was part of a research project. They were told about the changes made to the teaching method. They were also told that they would be asked to complete a number of questionnaires, before, during and after the module. We also asked for volunteers to act as Class Representatives, who we met at regular intervals. These students were able to provide us with feedback on the feelings of the class about the way that the changed module was progressing. We also attended all classes as observers.

Co-operative Learning in Practice

Part of a lecture on rotational motion is summarised in Table 1. Figure 1 shows one of the Class Questions. Applying the method of informal co-operative learning, the Class Questions were displayed and the students were asked to think about the question silently, on their own, for one minute, and then discuss their solution briefly with a partner. The quiet period was to allow all students an opportunity to think about the question. The partner provided (i) a person for discussion, (ii) the possibility of exposure to different views and approaches, and (iii) support because any answer was based on the thoughts of two people. After student discussion, a member of the class was randomly selected to answer the question. Sometimes the lecturer might ask for a second opinion, or for comment on the solution, or for a show of hands on differing suggested solutions. Discussion following responses to the question was encouraged, particularly if the solutions indicated some difficulty with the concept involved. The questions posed sometimes provoked more extensive discussion than at first envisaged.

Place the following shapes in order of increasing moment of inertia about an axis normal to the surface passing through the center of shape. (All the shapes have the same thickness and surface area, and are of constant mass per unit volume.)

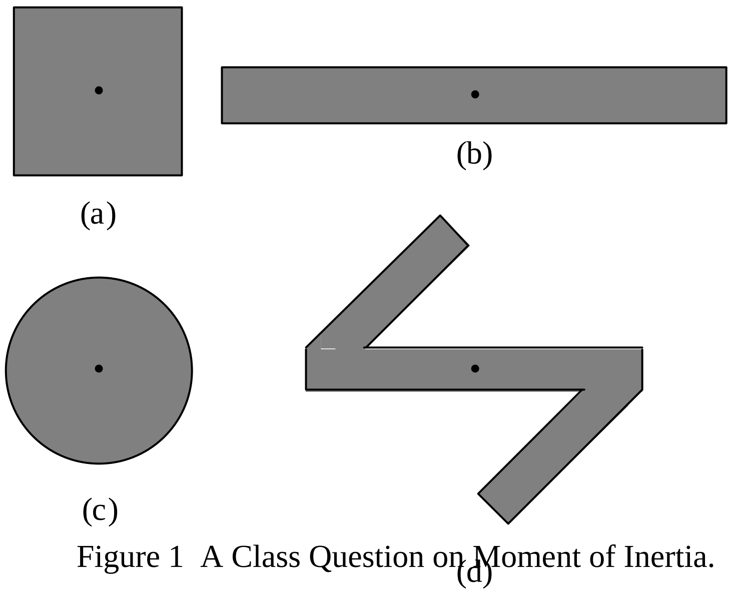

Figure 1 A Class Question on Moment of Inertia.

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Section	Outline	Class Question
Centre of mass	In the treatment of linear motion all masses were treated as point masses. Therefore the material on rotational motion was prefaced by a discussion of distributed mass, and the concept of the centre of mass.	*A template of mainland Britain is cut out of plywood. How would you find the centre of mass of this shape?* This question required the students to think about the fact that the force (of gravity) acts along a line joining the point of suspension and the centre of mass.
Rotations about an axis	This established the equations describing rotational motion, drawing parallels with the equations of linear motion.	*A tangential acceleration implies a tangential force. Where does this force come from?* This question followed a demonstration of rotational motion.
Rotational kinetic energy	This established the equation for rotational kinetic energy and, by analogy with linear motion, the concept of moment of inertia and its relationship to mass in linear motion.	*Place the following shapes in order of increasing moment of inertia about an axis normal to the surface passing through the centre of the shape. (All the shapes have the same thickness and surface area, and are of constant mass per unit volume).* The shapes are shown in Figure one. The answer to this question required the students qualitatively to study the distribution of mass for each of the shapes. The similarity of the shapes was chosen to promote discussion about the distribution of the mass.

Table 1 Summary of Part of a Co-operative Learning Lecture on Rotational Motion.

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Evaluation

The evaluation had three components: the knowledge and learning styles of the students before taking the module, their knowledge and learning styles upon completion of the module, and a summative descriptive evaluation.

The students completed a Contrasted Groups Design Learning Styles (CGDLS) questionnaire (James and Turner, 1998) and a Learning Styles Inventory (LSI) (Kolb, 1985) during the first teaching week. The CGDLS questionnaire allows students to describe, in a systematic way, how they go about studying. The aim of the questionnaire was to establish a *deep learning index* for each student. The LSI established their own feelings about their preferred learning style. During the same period the students also undertook a multiple-choice test called the Force Concept Inventory (FCI) (Hestenes *et al*, 1992). For comparison, the previous cohort (1997/98) of physics students also completed the CGLS and the FCI questionnaires.

The Level 1 students also completed the CGDLS and FCI questionnaires again in the first week of the second semester and their Mechanics examination scripts were analysed to see how they performed on the conceptual and traditional sections of the paper. The Mechanics examination results of the previous cohort were used for comparison.

The summative descriptive evaluation took three forms: at the end of the lecturing period the students completed the standard University Module Evaluative Questionnaire; before the examination the module lecturer wrote a reflection on his feelings about the good and bad features of the changes that had been made; after the examination results were known a Focus Group Enquiry with a self-selected sample group of ten students was conducted by a lecturer from another department.

The outcomes of the evaluation are summarised below. A more detailed discussion of the statistical analysis may be found in Booth and James (2001).

Quantitative Results and Discussion

Force Concept Inventory

The FCI test results for the previous cohort (1997/98) were significantly better than those for the 1998/99 cohort. Statistical analysis of the 1997/98 subgroup who did the FCI test indicated that they were representative of the cohort that took the Mechanics module. This suggested that the difference in results was not just because the weaker students did not progress from Level 1 to Level 2. Statistical analysis of the FCI test results for the 1998/99 students showed that there was no improvement in the results between the pre- and post-module tests, which was disappointing.

Contrasted Groups Design Learning Styles Questionnaire

No change in deep learning index was found for the 1998/99 students between the pre- and post-module assessments. This was partly expected since the changed form of teaching occurred in only one module out of a total of six taken by the students. It was noted that the range of indices for the 1998/99 students was narrower than that for the 1997/98 students, which may have reflected the greater maturity of this cohort, in that they were more prepared to express their own view rather than conform to what they perceived to be the 'correct' view. In all cases the majority of students had an index that

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indicated that they were tending to show surface learning styles as opposed to deep learning styles (note that strategic learning was not included in this assessment).

Learning Styles Inventory

Only the 1998/99 students completed the LSI. From the results, 55% of the class were assimilators, 27% were convergers, 9% were accommodators and 9% were divergers. It is interesting that nearly one fifth of the class had preferred learning styles that did not, in principle, match those associated with the programme of study that they were following (Kolb, 1985).

Analysis of Examination Results

Averages and standard deviations were calculated for the marks gained in different sections of the 1997/99 and 1998/99 Mechanics examination. For the 1998/99 students there was good overall correlation between the FCI score and the examination results. This was in strong contrast to the data for the 1997/98 students, which showed no correlation between the FCI score and examination results. These results are shown in Table 2.

	Test 1 1998/99		**Test 2 1998/99**		**1997/98**
	Conceptual	Traditional	Conceptual	Traditional	
Section A	0.25	0.40	0.12	0.41	-
First B question	0.53	0.69	0.51	0.61	-
Second B question	0.53	0.03	0.44	0.04	-
A and B	0.63	0.49	0.55	0.46	-
Exam mark	0.65		0.62		0.04
5% LOS	0.2874				0.3306
1% LOS	0.3979				0.4545

Table 2: Pearson *R* Correlation Coefficients for Correlations between Exam Results and FCI Score. Section A contained a collection of short compulsory questions (20 marks in total). Section B contained four long questions, from which students selected two (40 marks per question). Section A was a mixture of conceptual and traditional questions whereas in Section B each question contained both conceptual and traditional parts.

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Qualitative Results and Discussion

Module Evaluative Questionnaire

Tables 3 and 4 summarise the responses of 33 replies out of a group of 52 students.

Question 1 *'Overall, how satisfied were you with this module?'*		Question 2 *'In response to the statement "Would you recommend this module to a friend?" Do you:'*	
Response	Frequency	Response	Frequency
Extremely satisfied	4	Very strongly agree	4
Very satisfied	15	Strongly agree	11
Satisfied	12	Agree	16
Neutral	2	Neutral	1
Dissatisfied	0	Disagree	0
Very dissatisfied	0	Strongly disagree	0
Extremely dissatisfied	0	Very strongly disagree	0
No reply	0	No reply	1

Table 3 Replies to Module Evaluative Questionnaire Questions 1 and 2.

Question 3 *'Features liked.'*	Question 4 *'Features disliked.'*
Class involvement (22)	Random selection method (7)
Use of printed notes (18)	Missing parts of equations (6)
Demonstrations (11)	Class questions (4)
Quality of the lecturer (5)	Printed notes (3)
Interesting lectures (4)	
Teaching method (4)	
Relaxed atmosphere (5)	

Table 4 Summary of Replies to Module Evaluative Questionnaire Questions 3 and 4. Numbers in brackets show the frequency of the comment.

The results indicated that the students felt positively towards the changes that were made. The dislike of some students for the process of random selection was anticipated, and we were pleased that only a few students commented negatively about this.

Module Lecturer

The response of the lecturer was that, overall, the changed module had been a great success. He felt that there had been considerable benefits to himself as well as the students, which had compensated for the extra work involved. He also felt that he "was teaching physics and not just showing students how to plug numbers into formulae". He did, however, express concern that "because a significant amount of class time was spent

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on thinking about and discussing concepts, less time was spent on presenting worked numerical examples".

Focus Group Enquiry

Ten students volunteered to attend the enquiry and were asked to consider three questions that we thought would provide useful information. The questions, and the consensus views to each, were as follows:

- After considering the way in which the Mechanics module was taught what would you consider to be useful or less useful?

The students thought that it was good that the lecturer was enthusiastic and 'taught' rather than 'lectured to' the class. They liked the interaction between the lecturer and the class, and the demonstrations. They found the gaps in the notes useful in lectures, but felt that it made catching up missed lectures difficult. They felt that the concepts were covered well, but that some of the worked examples were covered rather too quickly.

- How has the experience of learning in the Mechanics module affected or influenced learning styles used in other modules?

The students had not found it possible to transfer the learning style to other modules as these were taught differently. However, certain aspects of their behaviour were a consequence of the style of learning that they had experienced in Mechanics. For example, in discussions during break times the students identified different styles of lecture delivery. Some students had also experimented with an alternative technique to writing down the notes in the lecture by listening to the lecturer and obtaining a copy of the notes from another student afterwards. Some students expressed a desire for the teaching style of other modules to be changed.

- What were the reasons behind your choice of questions answered in the examination?

The students selected questions that related to topics that they had studied prior to coming to University, and with which they felt more comfortable. A question involving integration was avoided because of its mathematics content, and the last question on the paper was avoided because it was new material and it was covered towards the end of the module.

Conclusions

Making the changes to the lecture module proved to be quite challenging. We felt that having more than one person reviewing the material, thinking of (and providing answers for) Class Questions, selecting tutorial and homework questions, and writing the examination paper was beneficial, although it significantly increased staff time. Changing to a co-operative learning approach was therefore initially costly although, once established, continuation with the teaching method requires relatively little extra effort. Since completing the project we have found a text that would have been very helpful in developing Class Questions to promote a conceptual approach to Mechanics (Mazur, 1997).

The student comments in the Focus Group Enquiry and the comments from the lecturer indicated that the changes were very successful from their point of view, simply because

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all involved enjoyed the experience. This supports the view that attitude affects learning and the students enquired why other modules were not taught this way.

We were disappointed that we could not show an improvement in either deep learning index or the conceptual understanding of Mechanics. Since the changes only covered one module we did not expect a change in the deep learning index. However we had hoped for an improvement between the first and second FCI tests. It is possible that the students did not treat the second FCI test with the same seriousness as the first. It is also possible that, since over half the class have a preferred learning style that theoretically copes well with more formal lectures, the changes introduced were sufficiently challenging over such a short timescale that little discernable change could reasonably be expected.

One consequence of the change in teaching method was an accompanying change in the content of the examination paper. The much greater correlation between the FCI scores and examination results for the 1998/99 cohort might be interpreted as an indication that the 1998/99 paper was a better test of the students' abilities in the conceptual aspects of Mechanics than the 1997/98 paper. However, some caution was exercised when making changes to the style of the paper, as it would be unfamiliar to the students. Also it had to be structured so that we could analyse how well the students performed in traditional versus conceptual parts. Ideally, there should be greater integration of these two parts and this did occur on the paper in the following session.

Although the changes introduced to the module could not be shown to be effective in the cognitive domain there was some success in the affective domain. We therefore believe that the changes did improve both the students' and the lecturer's experience of the module, justifying the time and effort involved. We also believe that an additional benefit was that the nature of the interaction between the students and the lecturer gave greater emphasis to the need to understand principles as well as to be able to put numbers into existing formulae. Pressure of time in lectures often means that we pick the solution to a problem that, 'magically', turns out to be correct. In reality, we are often required to solve new problems, in which case an understanding of the concepts is at least as important as knowledge of the relevant theory and underpins the ability to learn, and thereby understand and apply, new material.

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