

THE USE OF CLASSROOM FEEDBACK SYSTEMS TO ENABLE ACTIVE LEARNING IN LARGE ENGINEERING MECHANICS CLASSES

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Abstract $\frac{3}{4}$ Many recent studies have demonstrated that concept tests followed by immediate feedback and peer discussion improves students' understanding of difficult concepts in science and engineering. These effects have been shown both in conventional classrooms and in wired classrooms where students respond to concept tests using a 'classroom communication system'. These systems enable interactive learning even with large numbers of students. Little is known, however, about how students experience this method of teaching and learning or about what contributes to their enhanced understanding. To explore this, and its implications for engineering teaching and learning, data is being collected from mechanical engineering students taking an introductory mechanics course using semi-structured interviews, minute papers, critical incident analysis, and questionnaires etc. Data on improvements in conceptual understanding are also being collected. The study examines differences in students' responses to, and experiences of three different peer discussion sequences and the contribution of different feedback methods (ie computer-generated, peer-generated and tutor-provided) to learning.

Index Terms $\frac{3}{4}$ Socratic Dialogue, Classroom Feedback Systems, Mechanics

BACKGROUND

In an attempt to deal with the issue of large classes and poor conceptual understanding some institutions in the US have harnessed developments in communications and information technologies to devise new ways of teaching in science disciplines. Two approaches are significant in relation to this paper, that of the Physics Education Research Group at the University of Massachusetts [1] and that of the Galileo Project of Harvard, in particular Peer Instruction [2]. Both these research groups have modified the traditional lecture format of physics education by focusing on students' understanding of basic concepts using a sequence of fundamental questions designed to engage students followed by feedback and peer discussion.

What is innovative about both these groups' approach is their use of a Classroom Communications System (CCS) to support the process of interactive learning in large classes; (sometimes referred to also as Classroom Feedback Systems). These systems enable teachers to present 'concept tests' (i.e. questions), to receive student responses and to provide immediate graphical feedback. The system

components include a computer and a data projector to present the concept tests, a set of handsets (transmitters similar to TV & Video remote controls) and sensors (receivers) that allow students to signal their responses to the concept test and software that allows class responses to be collated and immediately displayed by data projector for students to see (i.e. fed back to students). Tutors have the ability to identify from the computer display the names of students and the nature of their response (correct or not). From a pedagogical perspective one advantage of the CCS is that it reintroduces teacher-student dialogue into large classes: the teacher can modify instruction in an ongoing way based on the overall class response.

For the past three years the Department of Mechanical Engineering at the University of Strathclyde has been exploring the use of concept tests, immediate feedback and peer discussion in large classes. This was preceded by almost two years of preparation before teaching – specifically visiting and observing US practitioners and becoming familiar with modern theories of teaching and learning. The aim of the 'New Approaches to Teaching and Learning in Engineering' (NATALIE) initiative is to develop a new model for first year mechanical engineering that would, over time, be rolled out across the undergraduate degree programme. The emphasis has been to put active learning back into engineering education. This ranges from the use of Socratic Dialogue (question and discussion sessions with CCS in large classes) to aspects of Problem-Based Learning in design, to workshop/studio teaching in custom-built classrooms to the re-introduction of more laboratory-intensive work. The use of Classroom Communication Systems is looked upon as the simplest way of introducing active learning into a large classroom without significant use of staff resource (for example by splitting the class into smaller groups).

This paper describes the use of Classroom Communication Systems in the NATALIE project and provides an evaluation of that work carried out during the third year of implementation.

There are two main aims in the evaluation of NATALIE. The first aim was to explore students' perceptions of learning in the interactive classroom. Various studies have shown that this teaching methodology does improve students' learning [2] so this was not seen as an immediate issue. Generally, the students who normally would struggle below the 50% mark in a traditional exam

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are 'lifted' into a higher band: the grade distribution sees a positive change. This change in grade distribution has been similarly experienced during NATALIE; no formal statistical analysis can be realistically carried out since the syllabus has changed from previous years and no control group is used (essentially since the Department felt that the control group, who would be given traditional lectures, would be disadvantaged). Rather than put the emphasis of the evaluation on 'does it work' (it does, if the lecturers are doing it properly), it was decided to examine the students' perception – particularly in the context of the move from school to university. The Department has replaced traditional one hour lectures and afternoon tutorials and laboratory investigations – which the students are normally led to expect – with two-hour highly interactive sessions each week in a modified lecture theatre with about 120 students attending. (These sessions are also supplemented by a core design class which uses features of Problem-Based Learning). We were thus interested in how students experienced this learning environment and the teaching methods and how these influenced student motivation and study methods. Despite the educational research in science, little has been published about how students experience this method of teaching or about that aspects contribute to their understanding or how it affects their motivation to learn.

The second aim was to examine the effects of different classroom discussion strategies. The approach in Mechanical Engineering has been strongly influenced by the work of Mazur at Harvard and Dufresne et al. from the Physics Education Research Group (PERG) at the University of Massachusetts, Amherst. These research groups have pioneered somewhat different classroom discussion strategies. Mazur's approach is called Peer Instruction and it starts by having students think individually about a concept test before providing an answer: they then engage in peer discussion with neighbours and are re-tested. In contrast, the PERG approach begins with informal group discussion of the concept question followed by an individual (sometimes group) response and a class-wide discussion facilitated by the teacher. Although we have taken these discussion sequences from the writings of these researchers it should be noted that these are ideal types and that Mazur, and certainly PERG, do not stick rigidly to a specific sequence. Nonetheless, it is unclear from the literature which of these two discussion sequences might be best and under what circumstances. Both have been used by the NATALIE project, mostly depending on the topic being discussed, and there was some perception that Peer Instruction had a greater effect.

In 1998 the New Approaches to Teaching and Learning in Engineering (NATALIE) project modified a traditional lecture theatre so that it could accommodate up to 118 students sitting in groups of four. Originally the Better Education Inc. Classtalk wired system was used, but this was supplemented by Varitronics' Personal Response System (PRS), a fairly simple but cheap and effective system based

on infrared transmitters and receivers. Typically PRS is used to poll the class using multiple choice questions, It also allows students to indicate their level of confidence, but this feature has not been used in this evaluation. The results are then collated in the lecturer's computer and displayed as a histogram using a data projector. Class differences can be used as the basis for discussion and further questions. The lecture theatre, called the InterActive Classroom – also has advanced multi-media facilities. The InterActive Classroom has now been extended to the new Weir Teaching Cluster – a managed £1.2M suite of hi-tech classrooms consisting of several more InterActive ClassRooms with CCS and custom group seating, standard multi-media classrooms, seminar rooms and a new Teaching Studio, a copy of those found at Rensselaer Polytechnic Institute (RPI) [3].

The intake to first year Mechanical Engineering at the University of Strathclyde is typically between 110 and 120 students. The students are very highly qualified (amongst the highest in the University and in engineering in the UK in general). Around 10-15% are female and, unusual for most Scottish universities, a high proportion come from outside the Glasgow commuting area. The first year curriculum consists of 12 credits. Two of these credits are electives which allow the students to take any class they are interested in. Of the remaining 10 credits there are 3 credits for core engineering mechanics (mechanics and thermo-fluids), 3 credits for design, 2 credits for mathematics, 1 for computing & engineering analysis and 1 for electronics. The engineering mechanics classes are all taught in the InterActive Classroom as well as the mathematics tutorial and problem solving classes (next year's intake will have the whole mathematics class taught using the CCS). The design class is taught using Problem-Based Learning, specifically Mechanical Dissection. The engineering analysis class is taught in the Teaching Studio. Only the electronics class is taught in a traditional lecture format (although it is hoped this will soon change). In all of these classes the students work in the same groups of four. The groupings are decided at the start of the academic year from a simple questionnaire: this attempts to match students who stay in the same halls of residence, to match gender, to mix students who have different computing skills and to mix students who have entered from 5th or 6th year of school, or from further education. On the first day of the semester students are introduced to their groups and together take part in a full day of ice-breakers and team-building exercises around the campus (which is very successful).

Each session in the InterActive Classroom comprises a mixture of mini-lectures, demonstrations and question and answer sessions with PRS, technical videos, computer simulations and problem solving. A relaxed atmosphere is encouraged and usually (depending on the tutor's idiosyncrasies) music is played. Group work – active collaborative learning – is encouraged during class. The students must sit in their groups in every class and are expected to work in their group outside class – to support

this, group homework exercises and simple design studies are also used.

EVALUATION

The results of a systematic evaluation, involving interviews with students, are summarised here. The full results will be published elsewhere.

All students in the interviews reported that they enjoyed the Natalie teaching approach when compared with traditional lectures and school based classes. When asked why the students made comments such as: they were more actively involved; that concepts were better explained; the atmosphere in class was more relaxed and 'laid back' in comparison to traditional classes.

There was also a consensus that the structure of the class with explanations by the tutor followed by concept tests and discussion, held their interest and attention for longer time periods than in traditional classes. In the latter classes, students felt that it was often difficult to follow what the lecturer was writing on the board or OHP and at the same time to listen and make notes. The result was that they often just took notes without really understanding the information. In contrast, in the Natalie class the students reported that they were 'taking in information throughout the class'.

The questionnaire data confirmed the findings of the interview data. The PRS approach was well liked by students (average of 1.4 on a 5 point scale: 1= strongly agree, 5= strongly disagree). Indeed the students believed that this approach should be used in other subjects (average = 2.0). When asked which other subjects the students mentioned Maths (16), Analogue Circuits (16) and two students wrote 'every subject'.

Almost all students felt that the PRS system forced them to pay attention (1.9) and that they had to think more (1.7) and were more actively involved during PRS classes than during traditional classes (1.6). The students didn't work more outside of PRS classes than traditional classes (3.0).

- *Like the way it's broken up with video and discussion...that is...you don't concentrate for long times on any one thing...you can see problems in two ways...in writing...then you can watch it on the video and see things working...*

The focus of the Natalie class is on understanding engineering concepts rather than on just being able to solve problems in a routine way. In the interviews many students reported that they were now beginning to understand concepts that they hadn't understood at school. At school some felt 'that they were merely able to solve a series of standard problems without fully understanding the underlying concepts. From the questionnaire data there was again clear support for these assertions.

There was consensus in the questionnaires that the use of the PRS method did help students to 'develop a better understanding of the subject matter when compared to traditional lecture based classes'. They agreed with the statement that this approach helped them to understand the concepts behind the problems (2), to relate concepts to real life applications (2) and to develop their abilities to question concepts and ideas presented by the tutor (2). Students also indicated that their memory for material was also better after a PRS class than after other classes (4= negative question).

In the interviews students provided a variety of reasons for their feeling that they had a better understanding of the subject matter: e.g. the concept is presented clearly by the lecturer; it is normally illustrated by examples; it is often demonstrated by video or graphically or through a practical tutor demonstration; there is peer discussion. Students felt that each of these components on its own and the combination of different methods all contributed to making the ideas and concepts more accessible.

The students' perception of a better understanding was also complemented by a change in their responses to Minute Papers. A subtle change of emphasis in the 'technical' questions could be seen: in broad terms – without getting too technical here – this changed from "I still don't know how to calculate this" to "I still don't understand that concept". This was a clear indication – which probably should be studied at another time – that the students were indeed thinking more about their learning.

All students interviewed were positive about peer interaction. Many students made comments to the effect that explanations given by other students developed their understanding.

Other students said that it was easier to admit lack of understanding to other students and that this opened the way up for discussion. Still others reported that hearing different perspectives on the topic in the group helped strengthen their own understanding by making more links. Some students made classic responses such as it was easier to understand a concept explained by a fellow student who had just grasped it than the same concept explained by the lecturer who was on a 'higher plane'.

- *I think you can learn a lot easier from the people that are the same age as you...like...if they've just grasped it then they can explain it in sort of easier terms than the people...like in the lectures.*
- *If a peer understands it and you don't...it saves you having to stick your hand up and say to the lecturer...I have no idea what you are talking about.*

The questionnaire data confirmed the interview data. Students reported that discussing the questions with other students aids personal understanding (1.6) and that hearing other students explain problems in their own words when working in small groups helps them to learn (1.9).

Two interaction methods were compared within the evaluation (i) traditional Peer Instruction where students first

respond individually to a concept test and are then asked to convince their neighbour that they have the correct answer before being re-tested and (ii) peer discussion where students discuss the question as a group before making a first response then discuss again as a group before retest. In the interviews there was a clear preference for the first interaction method. Some students reported that thinking individually benefits later participation and learning in the group: 'everyone has to think about their own answer and therefore everyone will have input when it comes to group discussion' and 'having time to think individually helps later when they moved to when we discuss...then you could learn better from your mistakes'. The disadvantage of starting with group discussion according to the students was that if you are unsure of the answer to a question you are more likely than with Peer Instruction to not think as deeply and/or be swayed by others and/or just trust in other students. However a few students did identify some occasions when peer discussion at the beginning might be preferred. This was when the concept test was very hard and it would be difficult for individual students to make a start. On these occasions group discussion would allow all the students to pool their resources and explore the territory.

The questionnaire data again confirmed the general findings from the interview data. Overall, students felt that it was better to answer the concept question individually before discussion in small groups (2). When asked to give a reason for this response the common view was that thinking by oneself before discussion helped learning because:

- *It forces you to think about it and not just copy someone else's answer*
- *You can see where you have gone wrong in your original answer and learn from it*
- *It forces you to have an opinion and reason behind your opinion*
- *It can help you identify misconceptions if you think individually first*
- *By the time you discuss it you all have your own opinions so you are less likely to think about their answer and just agree with other people*
- *It gives you different opinions rather than one group member knowing the answer and telling you*
- *It makes you reason your point of view before explaining it to others*

The above comments were reinforced by the fact that the majority of students agreed with the comment that group discussion after making an individual response leads to deeper thinking about the topic (2).

As a cross check on which interaction method was preferred, students were also asked to respond to the question – using PRS it is better to start with a small group discussion before making an individual response. There was strong disagreement with this statement (4) and the reasons were consistent with the comments made above:

- *because someone might come up with an answer before you do and then you don't think about the answer so much*
- *by doing that you let others do the thinking*
- *you may think you are right and then get talked out of it by someone in the group*
- *I don't think that everyone would think about the question properly...some people would go with other people's answers.*

When asked whether the best interaction method depended on the difficulty of the question, there was a mixed response (3). From those who commented, most students still felt it was always better to start with an individual response but a few felt that if the question was really difficult then an individual response may not be possible and a group discussion might help to unpack the question:

- *Whatever the question it is important that each individual thinks for themselves before thinking as a group*
- *Sometimes you don't know where to start with a question on your own and you just guess*

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