Taking the MICK: What is a Mathematics Interactive Classroom Kit ?

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This article follows on from Michael's contribution to the last newsletter: "Do Mobile Interactive Classrooms Help Academics Engage Learners, MICHAEL?" and attempts to give a feel for both the technology of interactive classrooms and the underlying pedagogical issues

The Interactive Classroom

"Wouldn't it be great if lecture theatres had a bank of screens at the rear, allowing a lecturer to see what students were thinking?", asked Prof Phil Race during one of his recent workshops on the teaching of large groups. Besides the fact that the images displayed would probably include beaches, beer and bodies, rather than mathematical symbols, there are at least three further problems:

1.) students don't like having electrodes implanted in their brains
2.) the lecturer would be overloaded by all the information on multiple screens
3.) interaction between lecturer and students is not promoted by the screens

An interactive classroom addresses these problems and many others! Firstly, a less painful way of probing the minds of students during a live class is to ask them questions, but the problem remains as to how you deal with the answers. They could be written down, discussed in groups, given by selected volunteers and so on. A Mathematics Interactive Classroom Kit[1] (MICK) helps gather responses to questions from all students, presents them to a lecturer in a more manageable form, enables group feedback to be given and allows all students to ask questions anonymously if they do not understand. The opportunity for students to give anonymous answers and ask anonymous questions encourages the weakest students to participate without fear of embarrassment. Objective questions can be marked automatically with or without immediate feedback to students. The lecturer can see how well the class is progressing while questions are still being answered.

Expressing all this another way: the bank of screens is designed to give immediate feedback to the lecturer. Computer assisted assessment is a more practical use of technology for giving immediate feedback to students, but what if you want immediate feedback for both lecturer and students? What tools are available to help a lecturer make live classes more interactive? A conventional Powerpoint presentation or an interactive whiteboard do not fulfil that role. An interactive classroom does.

A Classification Scheme

I have found it convenient to classify my own use of interactive classrooms into four types as illustrated in Figure 1. A Rudimentary Interactive Classroom Kit (RICK) involves the basic use of a group response system with handsets, such as PRS (McCabe, Heal and White 2001) and CPS. For example, plain text MCQs or simple numeric questions are easily presented in PRS (Figure 2), but a second screen is normally required, e.g. to display mathematical symbols or diagrams. A Dynamic Interactive Classroom Kit (DICK) provides a much slicker

[1] MICK = a computer network + interactive classroom software. The main software product used here is called Discourse. See http://www.ets.com for further information.

method for delivering questions via a group response system by eliminating twin screens and allowing greater class interaction. Its main benefits are:

- integrated delivery within existing Powerpoint presentations
- simplified operation using a single key or mouse click
- dynamic display of results (described below)
- display of feedback on the correct answer
- dynamic student feedback (described below)

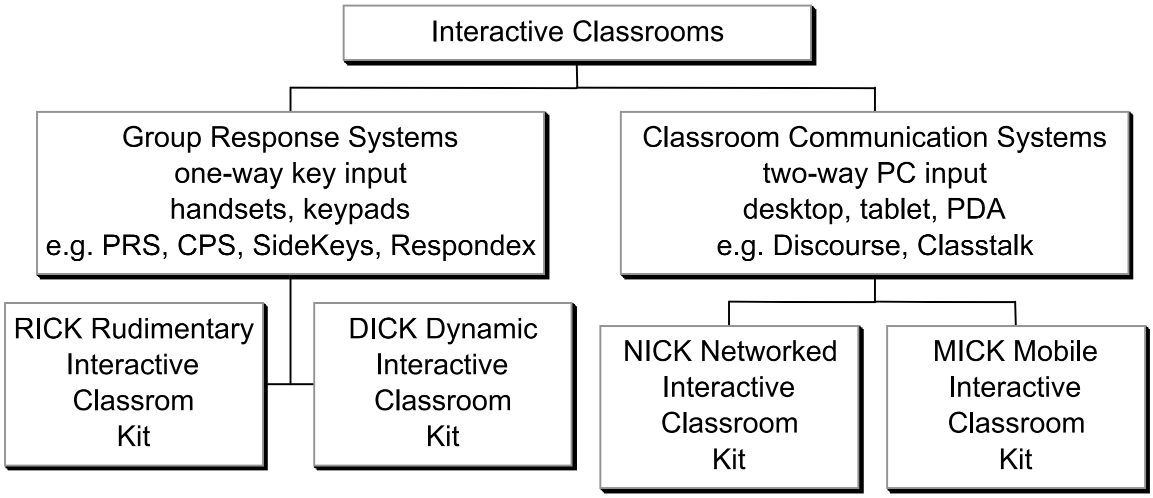
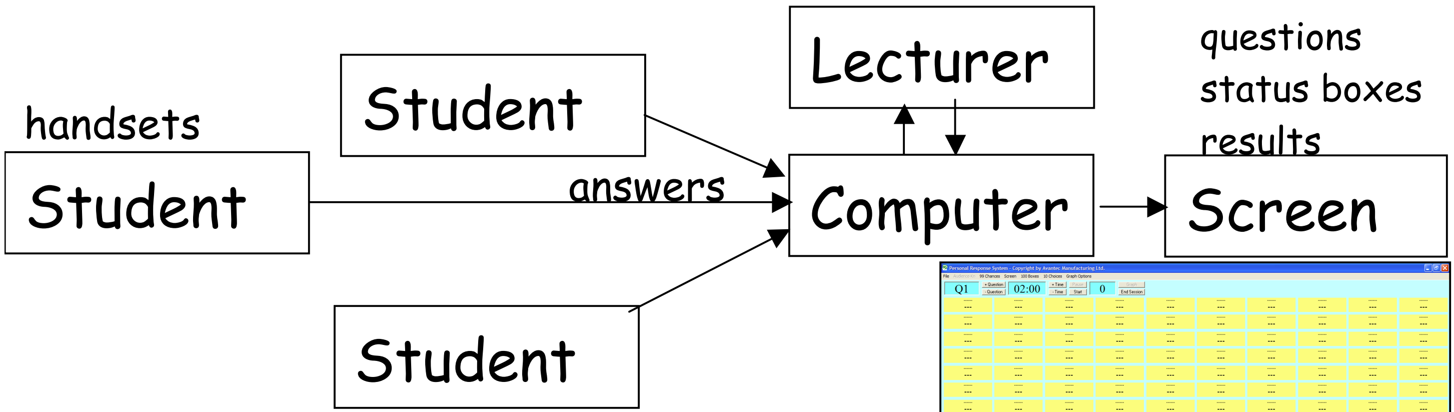


Figure 1 My Classification Scheme for Interactive Classrooms



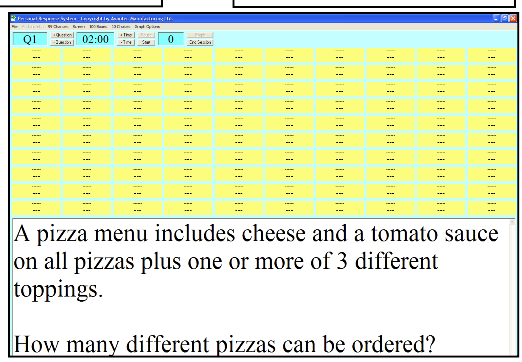


Figure 2 Group Response System using a Rudimentary Interactive Classroom Kit (PRS)

The DICK software I have been using is called RxShow, which can be used with a range of different handsets including PRS. An interactive classroom is often used most effectively when 'peer supported learning'[2] is exploited, typically with the following PSL stages:

1. Development and selection of question

[2] This is my preferred terminology for what is known as 'peer instruction' in the US

2. Question delivery
3. Cooperative group work
4. Collection of answers
5. Display of results (divergence)
6. Class discussion with optional iteration of stages 4 and 5
7. Closure (convergence)

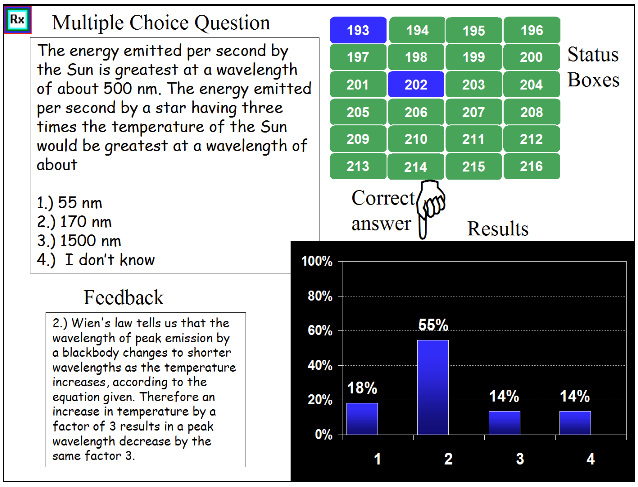


Figure 3 Group Response System using a Dynamic Interactive Classroom Kit (DICK)

Dynamic display of question results using RxShow allows stages 4, 5 and 6 to be combined and allows "dynamic peer supported learning". Instead of a static bar chart showing the frequency of responses, students can change their responses and observe the bar charts responding immediately. Interestingly, it has been found that results can converge, diverge, oscillate or even exhibit chaotic behaviour as students react to what they see. Could there be a simple non-linear mathematical model, which describes the behaviour of such a class?

Dynamic student feedback is an intriguing idea. RxShow allows selected slides to be specified as questions within a Powerpoint presentation. What about the other slides, which deliver straight content? Can they be made interactive too? One way of maintaining student focus is to include a numeric box on every slide, which continuously displays the 'mean student level of understanding' (or any other property) on a scale from 0 to 9. Students keep pressing their handset buttons to record how well they are following the class. While I have tried this out successfully at the beginning and end of a lecture, I have not yet been daring enough to include this option on all slides! Indeed do lecturers really want such real-time feedback?

The other type of interactive classroom, which I use, is the Classroom Communication System (McCabe and Lucas, 2003a,b) which allows two-way electronic communication between lecturer and students (Figure 4). It may seem obvious, but it does need to be emphasised, that a CCS should support and not replace normal means of human communication. Classtalk was an early CCS for use in mathematical subjects, but it was rather clunky. The CCS software tool, which I have been using, is called Discourse. It is either delivered in a computer teaching lab via 20 networked desktop PCs (NICK) or via a mobile, wireless system of 9 tablet PCs (MICK). Just to cause confusion, the 'M' in this context stands for Mobile rather than Mathematics

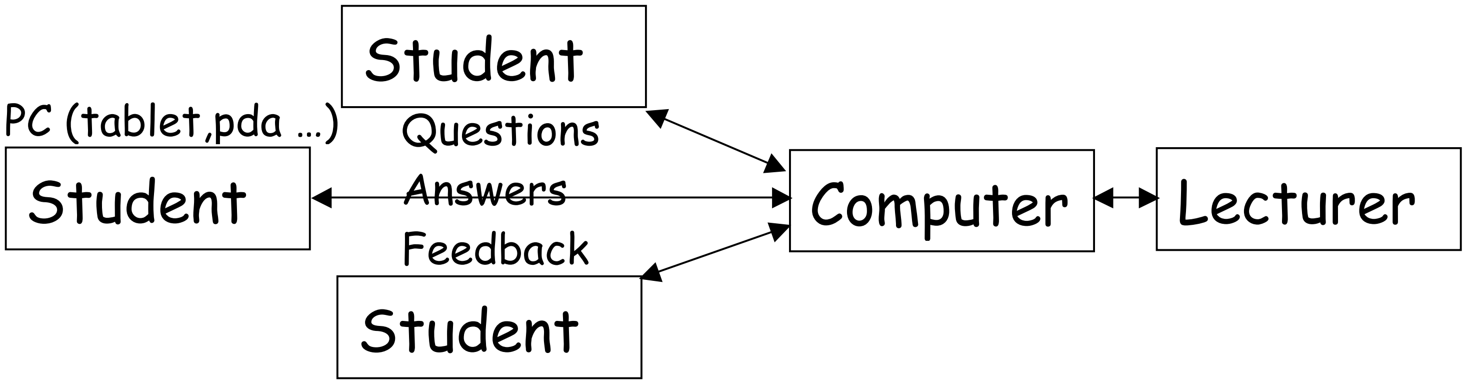


Figure 4 The Essence of a Classroom Communication System (NICK and MICK)

(and at other times I use it to stand for Managed!). RICK, DICK, NICK and MICK have become convenient acronyms for my classification scheme (Figure 1).

Let me show you some examples of how Discourse can be used in a classroom communication system for the delivery of some simple mathematics questions.

Questions and Answers

The Maths Café, which provides informal mathematics support for students at the University of Portsmouth, recently ran a Christmas Quiz sponsored by a well-known pizza company. Suppose we take a simplified quiz question and deliver it to students in a Discourse interactive classroom (Figure 5)

Figure 5 Student Answer to a Mixed Numeric and Text Question

Each student can use the slider to select a numeric answer between 1 and 25. Only the lecturer sees the values live on a single screen and can switch to viewing the collated group responses as a bar chart or pie chart (Figure 6). Individual feedback on the correctness of answers is not always provided in Discourse, but its strengths are not as mathematical CAA software. Group feedback can be can be given by the lecturer in a variety of ways: verbally only, by presentation of selected answers or by sending the graphical charts to the class. Already there is greater control of what happens than when group response system handsets, e.g. PRS, are used, but there is much more to offer in an interactive classroom.

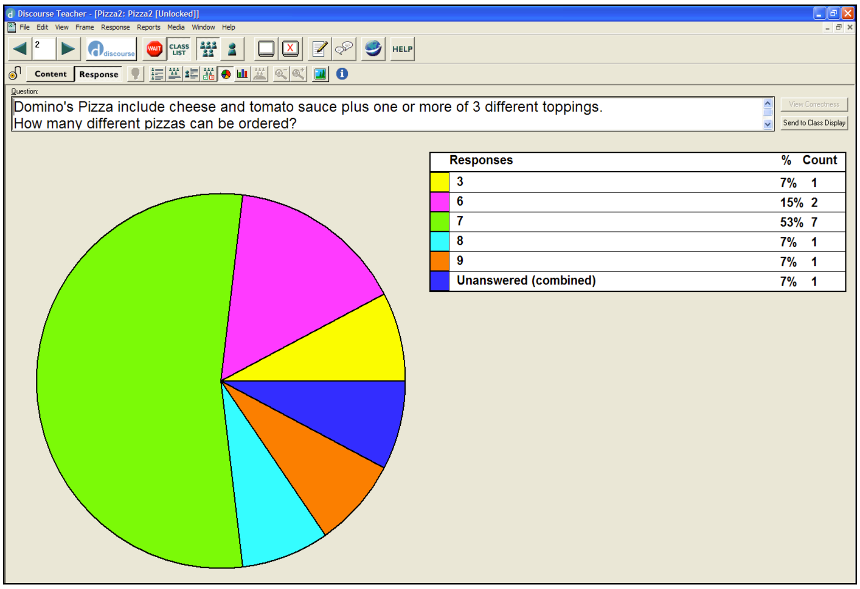
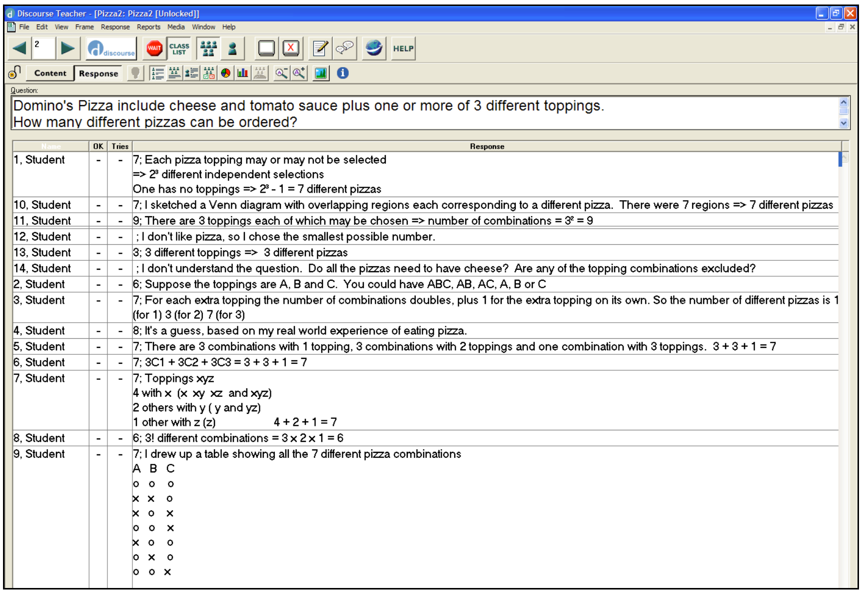


Figure 6 Lecturer Display for Optional Feedback to Students

The question additionally asks for an explanation. Some students might have guessed a correct or incorrect answer, others might have used a valid method to get an incorrect answer or used one of several valid methods to get a correct answer. Figure 7 shows how the lecturer sees both the numeric and text responses for each student. It is remarkable how many different ways there are of answering such a simple mathematical question.



Question:
Domino's Pizza include cheese and tomato sauce plus one or more of 3 different toppings.
How many different pizzas can be ordered?

Name	OK	Tries	Response
1, Student	-	-	7; Each pizza topping may or may not be selected => 2³ different independent selections One has no toppings => 2³ - 1 = 7 different pizzas
10, Student	-	-	7; I sketched a Venn diagram with overlapping regions each corresponding to a different pizza. There were 7 regions => 7 different pizzas
11, Student	-	-	9; There are 3 toppings each of which may be chosen => number of combinations = 3² = 9
12, Student	-	-	; I don't like pizza, so I chose the smallest possible number.
13, Student	-	-	3; 3 different toppings => 3 different pizzas
14, Student	-	-	; I don't understand the question. Do all the pizzas need to have cheese? Are any of the topping combinations excluded?
2, Student	-	-	6; Suppose the toppings are A, B and C. You could have ABC, AB, AC, A, B or C
3, Student	-	-	7; For each extra topping the number of combinations doubles, plus 1 for the extra topping on its own. So the number of different pizzas is 1 (for 1) 3 (for 2) 7 (for 3)
4, Student	-	-	8; It's a guess, based on my real world experience of eating pizza.
5, Student	-	-	7; There are 3 combinations with 1 topping, 3 combinations with 2 toppings and one combination with 3 toppings. 3 + 3 + 1 = 7
6, Student	-	-	7; 3C1 + 3C2 + 3C3 = 3 + 3 + 1 = 7
7, Student	-	-	7; Toppings xyz 4 with x (x xy xz and xyz) 2 others with y (y and yz) 1 other with z (z) 4 + 2 + 1 = 7
8, Student	-	-	6; 3! different combinations = 3 x 2 x 1 = 6
9, Student	-	-	7; I drew up a table showing all the 7 different pizza combinations A B C o o o x x o x o x o o x x o o o x o o o x

Figure 7 Lecturer Display of Numeric and Text Answers

One or more answers can now be sent back to the whole class for further discussion. For example, Figure 8 shows a subset of correct numerical answers illustrating the variety of possible explanations. Alternatively, one or more incorrect answers could equally well have been singled out for comment. A far greater variety of interactions become possible than when a group response system is used. The issue is now whether the brain of the lecturer can handle the variety of answers and respond to them in real-time. In practice, the overload problem can be dealt with simply by reading only a few explanations. Other students will never know that you did not have time to read theirs and there is always the option of reviewing the saved answers before the start of next class!

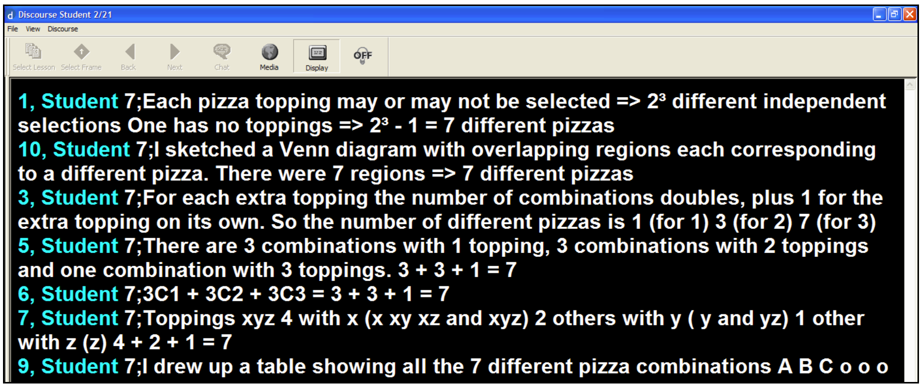


Figure 8 Student Display of Selected Class Responses

Algebraic Questions and Answers

Considerable work has gone into the development of sophisticated CAA for marking algebraic answers, from Maple TA to AIM and my own humbler efforts for Mathwise. Questions with very simple algebraic answers can be marked by Discourse, but it is usually much better to leave them as open-ended questions. Figure 9 (left) shows how students can enter algebraic answers using a special input tool and how a lecturer sees them together with an optional explanation (right). Once again, the lecturer can decide how to proceed: moving on to the next question, displaying correct or incorrect answers or displaying interesting or false explanations.

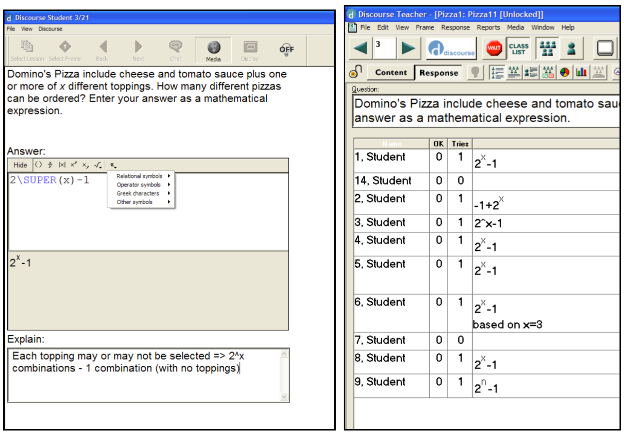


Figure 9 An Open Ended Question and Algebraic Answers

Class Structure

A group response system with handsets can be used in many different ways: from asking the occasional question within a lecture to a continuous set of questions, as might be used during a revision class. The same applies to the use of a classroom communication system such as Discourse, but with many more question (exercise) types and delivery options available, the structure of each class can vary considerably. Table 1 shows some of the variety possible during a Discourse CCS session. In practice, Discourse classes are better kept simple and the extremely full class in Table 1 would almost certainly overrun!

PURPOSE		**EXERCISE TYPE**
Introduction		
Structure/outline of class		IDP
Objective pre-test	Self-paced on previous class topic	MCQ x 5
Report on pre-test		REP
Any questions?		OEQ
Main session delivered in social mode, e.g. exploiting cyclical peer supported learning		
Poll existing knowledge/understanding of current topic		VOT
Summary of session aims		IDP
Begin with open (subjective) questions		OEQ/VOT
Move towards more objective questions		KWD/QAA
Use fill-in questions for text/numbers/algebra		FIB/ROT
Choice questions enable more precise feedback		MCQ/HSP
Any questions?		OEQ
Conclusion		
Poll knowledge/understanding of current topic		VOT
Five-minute paper		OEQ
Objective post-test	Self-paced on current class topic	MCQ x 5
Report on post-test		REP
Any questions?		OEQ

Key to Exercise Types

Open questions		Word questions		Information	
OEQ	open-ended question	KWD	keyword	IDP	idea presentation
VOT	voting question	QAA	question and answer	RPT	report
Fill-in questions		**Closed choice questions**			
FIB	fill-in-blanks	MCQ	multiple choice question		
ROT	routing	HSP	graphic hotspot		

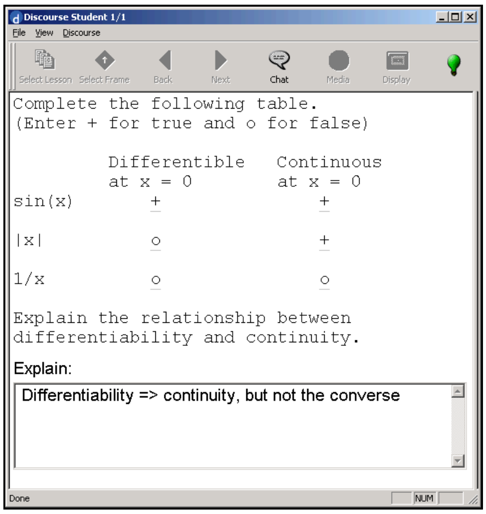
Table 1 An Interactive Class with Discourse

It begins with the lecturer sending "straight content" to each of the student PCs. This would normally be text and mathematical equations, but Powerpoint slides and Web pages are easily included. Next, several MCQs are asked. These may be discussed under lecturer control, e.g. using peer-supported learning, or delivered in a self-paced mode corresponding to traditional CAA with marking of individual questions and a final report. In the latter case the lecturer takes control at the end of the pre-test and is able to give group feedback. The benefit of using MCQs is that it is easier to analyse the responses and give feedback. The drawback of not knowing whether students guessed could be overcome by adding an explanation field.

Following the test the lecturer could use an open-ended question to ask for any questions. In practice, this would normally be done more traditionally, but it does illustrate the fact that:

a.) student questions can be asked and then recycled to the rest of the class anonymously
b.) a CCS involves two-way electronic communication – a lecturer may ask students questions and students may ask a lecturer questions

The main session exploits a wide variety of question (exercise) types. I provide a couple of examples to illustrate how two of these could be used in a mathematics class. Figure 10 (left) shows the student view when answering a Fill-In-Blanks question. Computer feedback on the correctness of each individual entry can be given independently or the table can be marked as a whole. Students can even keep changing their answer until it is correct. Meanwhile the lecturer (right) can monitor both the correctness of individual answers and the overall group results. In Discourse, all responses are seen keystroke-by-keystroke immediately they are entered, so the lecturer is free to make comments or give verbal assistance at any stage. Any number of responses or a chart of results can be sent back to students for further discussion. A CCS can thus be used to combine automatic computer feedback with manual feedback from the lecturer.



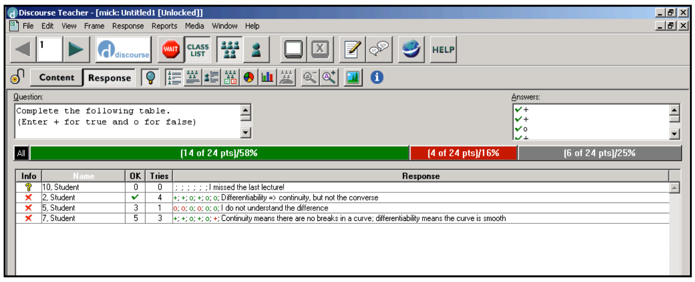


Figure 10 A Fill-In-Blanks Question Requiring an Additional Explanation

An interesting extension to the FIB question is the "routing" question. The main difference is that the sequence in which blanks are filled is not left-to-right and top-to-bottom, but may move in any pre-defined 2-D pattern. This is extremely useful in guiding students through numerical calculations, algebra or even simple diagrams. Although Discourse allows mathematical equations to be entered via its input tool, the alternative routing approach involves the creation of an "electronic worksheet". The idea here is to mimic the distribution of a paper-based skeleton worksheet, which students have to complete. The traditional approach would be for the lecturer to walk around the class, look over random shoulders and then try and give helpful feedback to everyone else. In the electronic version, the lecturer can see at a glance how far students have progressed through the worksheet and how well they are doing. The options for giving feedback with or without lecturer intervention are the same as a FIB question. Figure 11 shows the student view of an electronic worksheet. Rather than disturbing the rest of the class, student could be asked to enter questions electronically in the explanation box. The lecturer could then choose whether to respond verbally or electronically. A CCS, such as Discourse, provides a wide range of tools, which a lecturer can choose to use or ignore and stick to more traditional methods.

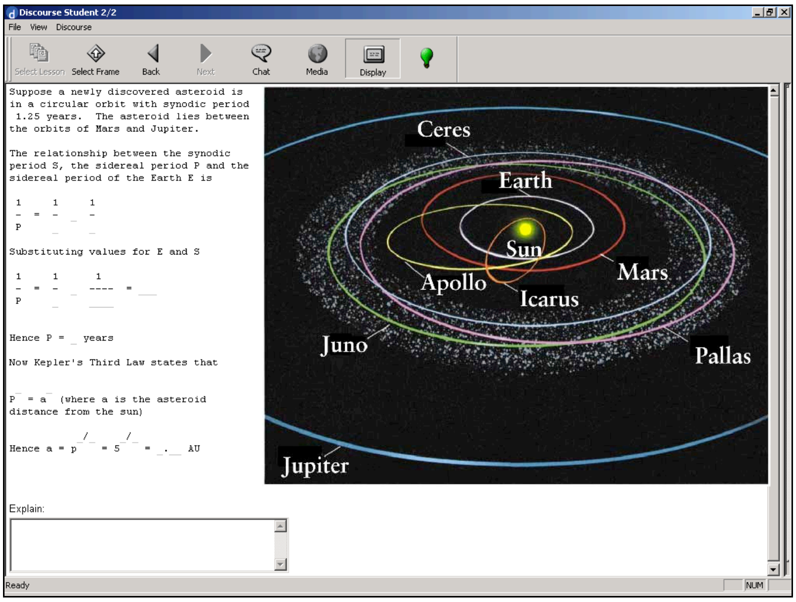


Figure 11 An Electronic Worksheet Delivered as a Routing Question

Not all questions need to be as involved as a routing question or even a multiple-choice question. A well-documented technique for concluding a class is to ask students to write a "five-minute paper" summarising what they have learned in the class, or alternatively, to ask what they have understood least. Open-ended questions like these are easily asked, allowing answers to be collected anonymously and discussed either immediately or at the next class.

Advanced CCS Delivery

There are potentially even more powerful ways of using the Discourse CCS. Questions can be delivered alongside a specified Web page and students must study the page(s), in order to help them answer a question or to provide further background. Figure 12 shows an example from a simple class on inequalities, which linked to a page from the excellent NRICH site. This approach could be taken further by delivering CCS questions alongside an on-line course, say in WebCT.

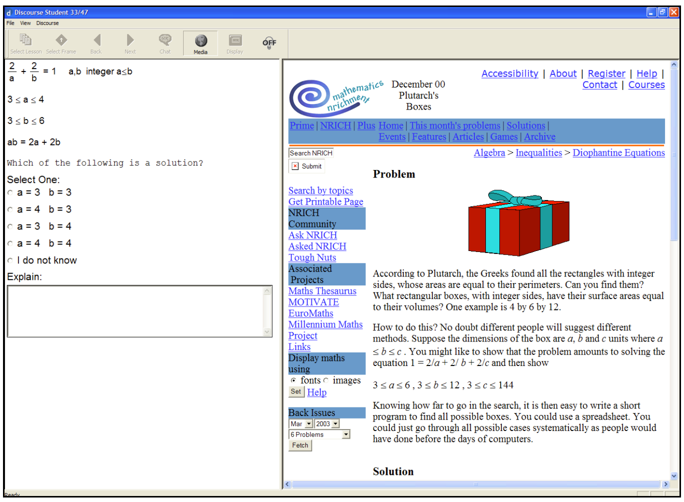


Figure 12 A Multiple Choice Question with Web Travel

Another approach is to get students to use mathematical software while answering interactive questions. I have tried this out in a first year problem solving class, which teaches students to use Maple. Discourse can simply be used to monitor whether students can use the software or to guide them through the solution of extended problems.

Questions about Questions

There are many questions raised by the use of live questions in an interactive classroom. Some have relatively straightforward answers; others do not and are still under investigation. Some relate to the technology and others the pedagogy. Some focus on the barriers to use of interactive classrooms, others focus on how existing tools can be used most effectively.

Q: How much does an interactive classroom cost? A: The PRS group response system is not expensive and the Discourse CCS can be set up for a similar cost on an existing computer network. Cost is not the main barrier to their use.

Q: You cannot deliver so much content in your lectures, if you keep breaking off to ask questions. Is the extra class time worth it? A: That's still an open question, but student evaluation suggests that there are significant benefits from interactive questioning.

Q: How many interactive questions can be delivered in a hour? Far fewer than anticipated, because of the time it takes to ask the question, collect answers, discuss the results, change answers and discuss the correct answer.

Q: Where should interactive questions be placed within a lecture? It depends, but students generally report a preference for interactive questions interspersed at regular intervals during a class. Questions maintain student attention by breaking up the class.

Q: What proportion of time is spent on different stages of questioning? A: The time spent on content delivery and stages of interactive question delivery can vary significantly (Figure 13).

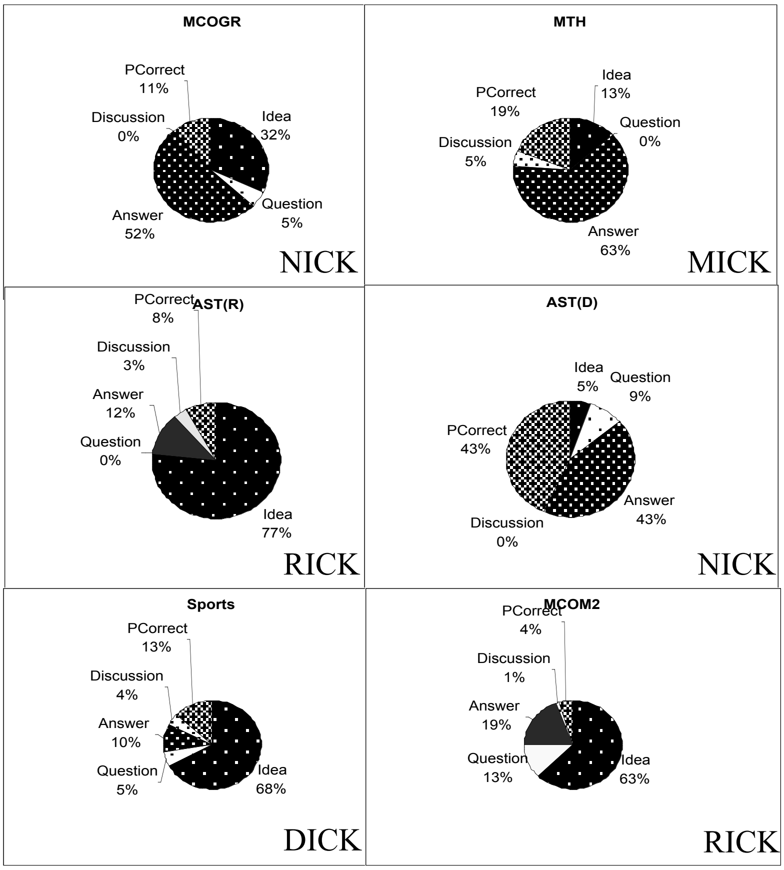


Figure 13 Time Spent on Content (Idea) versus Question Delivery During Interactive Classes

Q: Do students find that the dynamic display of results provides useful feedback? A: Yes

Q: Do weak students benefit more than stronger students from interactive classrooms? This may well be, but I have no evidence.

Q: Is a classroom communication system better than a group response system? Not necessarily. A group response system is much simpler to use.

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Q: Can an interactive classroom session be delivered on-line? A: This is possible with the Discourse CCS, but I have not tried it outside one room

How should an interactive classroom be arranged to maximise its benefits?

Does class communication improve when a less intrusive mobile system is used? What type of questions work best? What is the difference between conventional CAA and CCS questions?

Q: What are the barriers to uptake? A: Time: question authoring, equipment setting up, question delivery; Money: software, hardware, room layout; Availability and ease of use … but in my experience it has been worth the effort

Q: How can interactive classrooms be improved? In many ways! Interactive classrooms are still in their infancy. This article only gives the flavour of what they can do at present.

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Products

Personal Response System, PRS	http://www.educue.com
RxShow	http://www.rxshow.com
Discourse	http://www.ets.org/discourse/