Original article

Using an electronic voting system in logic lectures: one practitioner's application

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Abstract This paper reports the introduction of electronic handsets, like those used on the television show 'Who Wants To Be A Millionaire?' into the teaching of philosophical logic. Logic lectures can provide quite a formidable challenge for many students, occasionally to the point of making them ill. Our rationale for introducing handsets was threefold: (i) to get the students thinking and talking about the subject in a public environment; (ii) to make them feel secure enough to answer questions in the lectures because the system enabled them to do this anonymously; and (iii) to build their confidence about their learning by their being able to see how they were progressing in relation to the rest of the students in the class. We have achieved all of these and more. Our experience has revealed that the use of handsets encourages a more dynamic form of student interaction in an environment – the lecture – that can, in the wrong hands, be utterly enervating, but they also provide an opportunity for the lecturer to respond to students' difficulties at the time when they really matter. In this paper, we discuss our case of rapid adoption, our grounds for judging it a success, and what that success seems to have depended on.

Keywords campus, formative, interactivity, lecture, philosophical logic, portable, summative

Introduction

Of all the topics taught to undergraduate philosophy students, philosophical logic can seem to be the most daunting, and not just for the students. Certainly, in the Faculty of Arts at the University of Glasgow, many students give every impression of being maths or symbol phobic and are horrified by the very idea of working with something that can look very much like algebra. They inform you of their dread in the preceding tutorials; they pass on greatly embellished horror stories of people who came a cropper in previous years; and then at the end of course in the feedback questionnaires there remains a stalwart few who provide some variation on the theme of 'If I had wanted to do Maths, I would have applied for entry to the Science Faculty'. It is true that they face a challenge in the classes that lie before them, and the challenge the lecturer faces is, consequently, no less substantial. Not only does the lecturer have to convince the students that this is a subject they can not only enjoy but succeed in, they also have to overcome the hurdle of the students' initial resentment to having to do it in the first place.

This course then is seen as particularly challenging to both students and staff, and led to the lecturer both introducing some new approaches and to initiating an evaluation study on their merits. This paper reports one aspect of that wider evaluation study into the use made by philosophy students of the full set of learning resources available to them. In that study, we were primarily concerned with three things: (i) finding out which resources offered the best support for good teaching and learning; (ii) carrying out an evaluation

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of traditional versus non-traditional methods of teaching; and (iii) assessing the relative values of alternative learning resources for teaching formal logic and the acquisition of abstract concepts to non-mathematically oriented students.

Our evaluation of the resources chosen by students followed the model of Integrative Evaluation (Draper *et al*. 1996), but used the 'Resource Questionnaire' as our main instrument (Brown *et al*. 1996). With this tool, we were able to measure, using student self-report, which resources students used at all, how much use they made of them, and how much they valued each one. The resources that we considered included lectures, the recommended course text (Tomassi 1999), student-led and non-student-led tutorial discussion, the use of the Personal Response System (PRS) or handsets (Draper *et al*. 2002) in lectures, electronic texts and electronic course materials, Web resources, access to the lecturer, handouts, the Library, and workshops – although there was a category for 'other' for those students who were ingenious enough to discover a resource we had not identified. The evaluator also observed the lectures on occasions when handsets were being used and on the odd occasion when they were not, and we used the handsets to evaluate the advantages and disadvantages of handset use in lectures. Finally, the lecturer provided written and verbal feedback after using the handsets in her lectures. While the results from the rest of the evaluation are discussed in Stuart and Brown (2003), in this paper, we focus on the most innovative of the resources: the handsets.

The use of an electronic voting system (or 'handsets') in lectures was adopted as a way of creating a more dynamic learning and teaching environment in which students are encouraged to engage with their difficulties and seek to resolve them. It was hoped that using this equipment would both promote learning directly, and address the lack of self-confidence described above as a major means to that end. In particular, it was hoped that it would achieve this by: (i) making students feel secure enough to answer questions in the lectures by providing anonymity; (ii) building students' confidence about their learning by their being able to see how they were progressing in relation to the rest of the students in the class; and (iii) getting the students thinking and talking about the subject in a public environment. With a great deal of previous experience of asking questions about how well students were understanding what was being taught and gleaning responses from the usual few conscientious and vocal students who tend to sit towards the front, the lecturer thought that this kind of device would enable her to provoke an entire class into responding to her questions. Thus the ambition was to extend the participation of the best few students to the whole class, and also to introduce a light-hearted tone to counter the atmosphere of foreboding associated with the course. The lecturer did, however, worry that the students might think of them as a novelty and become quickly bored with their intrusive use in the class; as we shall see, this anxiety was unfounded. Discussions with colleagues in the same institution showed that many had no wish to change their methods, despite the evident difficulties for the students; while presenting on this experience at the Learning and Teaching Support Network for the discipline elicited some enthusiastic responses from colleagues elsewhere who were predisposed to consider innovations.

The teaching context

There were about 140 students taking the second year philosophy class, and philosophical logic takes up approximately one third of the total lectures for the course. There are four topics in total in the course and students must answer on three of them in the examination, so logic is not compulsory, though taking it is strongly advised for those students who intend to continue into Honours in Philosophy. The class attendance varied in size from about 70 to 100 students. Some of whom will be, very wisely, hedging their bets and coming along to see if they can get the hang of it and, if they can, have another option in the examination.

The handsets were used in nine out of the twelve lectures. They had not been available in previous years, and on this occasion they were only incorporated into the class at the last minute when the lecturer was encouraged to use them by a colleague who was already successfully supporting their use in a number of other disciplines (Draper & Brown 2004). The lectures maintained their previous general format. Thus in this case, the lectures depended on preparation of examples that would be worked on in the lectures, but the questions were not prepared in advance, but spontaneously generated from and about the current

example being discussed, relying on the lecturer's previous experience of asking questions orally.

The handsets are like television remote control devices and are distributed randomly to every student before the lecture begins. The randomness is important since each handset is numbered and if the same student used the same handset each time, it would be possible to trace the individual responses made by that student and the element of anonymity would be lost. Students are asked multiple-choice questions, with up to ten possible answers, that they must think about briefly and respond to fairly quickly, and each student transmits the number corresponding to their chosen answer. The answers are then collected via receivers to a laptop that displays, via the room's projection system, a bar chart representing the distribution of the responses. In any one lecture, it was possible to ask between two and twelve questions, although it should be added that on top of those questions for which the handsets were used, the lecturer also asked quick questions that required a 'hands up' or verbal response. This was especially important since the class was also being (2-way) video-linked to six students at a remote campus and the lecturer did not want those students to feel that this slight difference in provision would make a big difference to their learning. When we used handsets, the lecturer asked the remote students to hold up the number of fingers that corresponded to the answer they thought was correct. So their fingers became the equivalent of the numbers 1 to 10 on the handset. When the lecturer asked questions without the use of handsets, the lecturer made sure to watch the monitor as well as the people in the lecture room to hear the first correct answer.

Types of question

The kinds of questions that can be asked vary quite considerably, but typical examples had only two or three possible answers. These were easier to respond to, and more importantly, quicker to ask. Example question formats included:

- 'If the options for the next stage in this proof are MPP or MTT which one would you choose? Press 1 for MPP. Press 2 for MTT.' (MPP is an abbreviation for *Modus Ponendo Ponens* and means to affirm the antecedent; thus if you have two propositions: 'If A then B', and A, then you can conclude B. MTT is an abbreviation for Modus Tollendo Tollens and means to deny the consequent; thus if you have two propositions: 'If A then B' and the denial of B, you can then conclude the denial of A.) [This is an example of audience participation in the next step of a multi-stage problem solving example: cf. Meltzer and Manivannan (1996).]
- 'Do you understand this proof?: Press 1 for Yes. Press 2 for No.' [Direct feedback to the lecturer cf. end of term course feedback questionnaires.]
- 'How would you categorise this statement? Press 1 for Tautology. Press 2 for Contingency. Press 3 for Inconsistency.' [Self-assessment testing of concept-instance links.]
- Discussion-initiators, which are described below. [Cf. the 'brain teasers' discussed in Draper and Brown (2004).]

The lecturer did also occasionally ask oral questions that required an open-ended (verbal) answer and then asked the rest of the class if they agreed or disagreed with that answer, using the handsets to record their response. This had the benefit of being interactive in two ways and worked well once the class had become comfortable with one another and with the handsets. This style of questioning also gave them slightly longer to think about their own answer and the chance to revise their initial response in the light of the answer that had already been given.

We discovered that quite quickly the students were in a position to identify the usual people giving the verbal responses and gauge their own follow-up responses on the past correctness of their responses. So this method became one that could be used only when the conscientious responders were not present, which was very rare, or when they had been asked not to be the first to answer, something the lecturer did not like to do because it might stifle their enthusiasm.

Once in a while the lecturer asked more complex questions about how well the class felt they were understanding the material and, although these sorts of questions were time-consuming and the responses were subjective, they were informative enough to provoke her to redirect her teaching. The most interesting of these question formats was one in which the lecturer asked them to give her their responses to each one in turn of the ten rules of logic that had been covered: the rules of Assumption, Double negation,

MPP, MTT, &-introduction, &-elimination, V-introduction, Disjunctive Syllogism, V-elimination, and Conditional Proof. For each, they had three possible choices:

- Press 1 for 'Dead easy'
- Press 2 for 'Difficult but I'm getting there'
- Press 3 for 'Dastardly'

The general results were that over a third of the class (39%) found none of them 'Dastardly'; that only two students found none of them 'Dead Easy'; and only one student found nine of them 'Dastardly' – the exception here was the Double Negation rule that he found 'Difficult, but I'm getting there'. However, the most unexpected thing that emerged was that many of the students found Disjunctive Syllogism (DS) more difficult to comprehend than V-Elimination (VE). 21.4% of the 56 students who recorded all ten votes found DS more difficult than VE. This was completely unexpected.

A surprise in the feedback to the lecturer

That this group of students should find DS harder than VE was surprising. Disjunctive Syllogism is by far the simpler of the two rules – even, possibly, to the untrained eye, as the reader may try below.

Disjunctive Syllogism (DS)

DS states that if you have P or Q and you don't have P, then you have to have Q, and vice versa. More formally:

given a disjunction:	P v Q
and the negation of one of the disjuncts:	¬Q
we can conclude the other disjunct:	P

V-Elimination (VE)

VE states that if Q or P follows from an (inclusive) disjunction of, for example, P or Q, then, because you cannot tell which of P or Q separately or P and Q together it is derived from you must take P by itself and prove Q or P and then take Q by itself and prove Q or P. That way you cannot derive Q or P invalidly.

More formally:

given a disjunction:	P v Q
and a conclusion:	Q v P

we must derive the conclusion from each of the disjuncts separately.

Thus our proof becomes (line numbers are given in parentheses; the first number refers to what line the current line rests on):

1 (1) P v Q	Assumption
2 (2) P	Assumption
2 (3) Q v P	2 VI (V-introduction)
4 (4) Q	Assumption
4 (5) Q v P	4 VI
1 (6) Q v P	1, 2, 3, 4, 5 VE

(The assumptions at lines 2 & 4 are discharged leaving the conclusion Q v P dependent only on the premise P v Q at line 1.)

The students' reversal of the difficulty of the two rules was not something the lecturer would have anticipated – perhaps it appeared just deceptively simple and they were reluctant to believe that it could be so easy – but by using the handsets, to enable them to answer questions without the fear of looking ridiculous, the lecturer had the opportunity to go back and adapt her teaching to address a topic that she would not have expected needed to be addressed, at the time that the students needed it. Any other year the lecturer would have had to spend time analysing their examination performance and, on the assumption that each class of students has the same problems, which in fact we know they do not, act the following year with the benefit of hindsight.

Benefits of handsets

One of the essential features of the use of this equipment is that both the students and the lecturer get to know the distribution of responses and, in confidence, how their own response relates to that distribution. The element of anonymity encourages everyone to contribute and, unlike in face-to-face discussion, each individual can express the choice they incline to rather than the choice they would feel able to explain and justify to others. In other words, they provide the student with the ideal circumstances under which they can try out their responses to questions without any fear of embarrassment if their answer turns out not to be right. The following selection of student comments confirms this.

They were elicited by the open-ended question, administered in the final logic lecture, 'Handsets have

been used for voting in some of your lectures. What are the benefits of this to students/lecturer? What are disadvantages of this to students/lecturer?'. This received 66 responses. While 47 (71%) mentioned negative ones, referred to below, 56 (85%) listed one or more positive features: these are illustrated here, with the number of students mentioning some form of each theme given in parentheses.

- 'Indication of students' gaps, not what lecturer thinks might be gaps.' (21)
- 'Students see how well they understand the material and compare their progress with others.' (20)
- 'The anonymity allows the student to show they're unsure of the subject without embarrassing themselves.' (16 mentioned this theme)
- 'It's anonymous – tend to be more honest! Also can compare answer to other peoples which can be very reassuring!'
- 'Compensates for lack of confidence, provides anonymity.'
- 'Encourages us to participate; more likely we will listen this way.' (9)
- 'People answer more willingly.'
- 'Easier to hold attention. Fun!' (9)

When students were asked their opinion of the usefulness of handsets in their lectures, 77% rated them useful, very useful, or extremely useful. (This class was not asked the question about net benefit widely used in other classes by Draper & Brown 2004.) What we have, then, is a new resource that changes the form of a very old resource, the lecture. Traditionally, lectures have been a period of time in which the student is a passive auditor and is being provided with knowledge from the person addressing them at the front. During the lecture, students can drift in and out of awareness of what is being said, and a reflection of this drift can be seen in the recurrent patchiness of most student lecture notes. However, even in an apparently excellent interactive lecture, where the lecturer is attempting to engage the attention of the students by asking questions, there will be just a few students who actually speak with the rest keeping quiet, and consequently, the state of understanding of most of the class remains largely opaque to the lecturer until the examination has come and gone. But, where handsets are being used effectively – engaging the best students along with those who might be struggling – they facilitate an interaction between the students and lecturer, which keeps the students thinking and concentrating on the material throughout the lecture.

To encourage student–student interaction, students were occasionally asked to answer a question without thinking about it for too long; they were then were asked to discuss it with their neighbour and answer it again. The shift towards a greater number giving the right answer on the second attempt was sometimes quite extraordinary, and it seems that the students who had a better grasp of the subject were able to convince their neighbour to change their mind and vote differently the second time. This is certainly one way to promote discussion of a subject like logic that most students would prefer to avoid, and which only the most unrealistically romantic of educators would expect them to discuss anywhere else.

In informal interviews, several students had said that they were more likely to try and work out the answer to a question if handsets were being used. So towards the end of the course we asked all students in the class if looking back over the course when they were given a problem to work out in a lecture, were they more likely to work out the answer if they were asked to answer verbally, 'hands up', or using handsets. The result of this question, which was itself asked using the handsets, is shown in Table 1.

Such results can only be interpreted as the students enjoying the interactive nature of the lectures, with their responses providing us with an overwhelming endorsement of the use of handsets to engage students and keep their attention. And, if they are more likely to work out the answer when they are using handsets, then this can only benefit their learning.

If students are to answer questions in ways that would be beneficial to them, that is, if they are not merely to guess, then they have to reflect more on what they have learnt and how they are learning. One of the most interesting things to come out of this study was that a number of students reported that this was indeed the case when handsets were used, and also that when they could see how well they were doing they felt much more confident about what, up to then, they had only thought they knew. It was also clear that the opportunity for students to think about their answers and discuss them with their neighbour also made a difference to their understanding. It seems likely that this was the result of having to generate arguments for

Table 1. Effect of different methods of answering questions on the likelihood of working out the answer.

Question number	Option: Given a problem to work out in a lecture, were you more likely to work out the answer if:	% of students who voted for each option
1	the class was asked for a verbal response	0
2	the class was asked to vote on one or more answers by putting their hand up	2
3	the class was asked to vote on one or more answers using the handsets	32
4	none of the above (i.e. I never try to work out an answer)	6
5	all of the above (i.e. I always try to work an answer out)	28
6	1 and 2 (i.e. verbal and hands up but not handsets)	2
7	1 and 3 (i.e. verbal and handsets, but not hands up)	4
8	2 and 3 (i.e. hands up and handsets, but not verbal)	26

and against alternative answers. There is no doubt that having to do this is a powerful promoter of learning, and unquestionably beneficial to the development of critical thinking skills. The conclusion here can only be that this is an excellent way in which to carry out formative assessment. And, of course, if this formative assessment is working well, the students will be in a strong position to let the lecturer know about the gaps in their knowledge, enabling the lecturer to turn their attention to what the students say they need, rather than what they think they need. Which, in turn, means that the lecturer is much less likely to try to second-guess or make unwarranted assumptions about the students' progress. However, none of this is valuable unless the lecturer is flexible enough to respond to the changing requirements of the class; an adaptability described rather aptly, since it is so far from the traditional idea of delivering a lecture and then leaving the room, by Draper & Brown (2004) as 'contingent teaching'.

A contrasting case

But, before we finish with only positive conclusions, we should mention the one or two problems that we encountered. The handsets, along with their infra-red receivers (and we needed three for the size of the lecture room), the visualiser or OHP, two screens (we used one to display the feedback from the handset equipment, and another for the OHP with the questions), and the PRS software on the lecture theatre computer, were all necessary and, unless you have a lecture theatre that is already fully equipped for PRS use, setting up can be a time-consuming job at the beginning of a lecture, or even in the ten-minute break between lectures. The only complaint we had from students in the Logic lectures was that the time to set the system up and running did occasionally eat into the lecture time and, if the lecturer started even though things were not quite ready, they found the setting-up that was going on around her disruptive. (Of the 66 students responding to the questionnaire referred to above, 47 (71%) replied to the question on disadvantages, of which 39 (59% of the sample, 82% of the disadvantages) reported that it could be time consuming.) However, on the one occasion that there were significant difficulties setting up the equipment they were local to the design of the particular lecture theatre and not PRS. The ideal situation would be one in which lecture theatres had the system built in to its functioning, so they could be used at very short notice by anyone taking a class in the room.

The only other problem that the lecturer experienced in the use of handsets was when she decided to try them out on another course, in a first year Philosophy of Mind lecture. The experience was not positive. The lecturer had too much material to get through with the class on that day and reported having felt herself becoming tense when there was a hold-up getting the PRS system to work. Even more unfortunately, the lecturer had not taken the handsets into account properly and had not realised that the sorts of questions she would be able to ask would be very different from the rather clear-cut questions that can be asked in a logic class. As a result, she asked enormously subjective questions like 'Do you feel that you have understood Behaviourism?', and found herself in the position of not being able to offer more clarity because of the limited amount of time available. This time limit also meant that she failed to discuss the voting with the students or even leave the

charts up for long enough for them to look at. But when the students were asked if they had enjoyed using the handsets they looked rather non-plussed but nevertheless gallantly replied 'Yes'.

It was not possible, for this lecturer in this context, simply to draw on past experience of asking numerous oral questions in order to generate handset questions on the spot. It would require some forethought and preparation of suitable questions, and equally an adjustment of the lecture plan since there was not already time allocated for asking questions by other means in this particular lecture, as there had been in the logic class lectures.

Conclusions

Students reported that lectures are an important resource in logic and this is borne out by the examination results when we compared two groups: those who attended the final logic lecture (where various evaluation measures were recorded) with non-attenders. Figure 1 makes the different results of these two groups clear.

From the lecturer's perspective, handsets are an important new tool, especially in larger classes where it is inherently impossible to get everyone to respond otherwise. The lecturer can obtain immediate feedback about what the students think they know and understand and, subsequently, they can redirect their teaching based on what the students feel weak on rather than on what they predict the students will find difficult. The students in the logic class did not regard the handsets as a novelty, become bored with them, or find them intrusive. The students in the Philosophy of Mind class did not have the opportunity to become bored with them and, if the lecturer had thought more carefully about the sorts of information she had wanted from them, they would not have had the opportunity to think of them as intrusive. The lecturer has no doubt that if she had taken time and planned ahead on that occasion, she would have learnt a great deal, which would have helped her pitch her lectures and address or re-address aspects of the course that, by now, she had begun to take for granted.

Even with the problems we have mentioned, it is possible to conclude that using handsets competently in lectures does engage students and encourages a much more dynamic form of student–lecturer and student–student interaction. Handsets enable all students, weak and strong, to think, to answer (anonymously), and get immediate feedback on their knowledge and understanding. They can see how well they are doing in relation to others and they report feeling more confident about what, up to then, they only thought they knew. If this tool is to be really helpful to the students, they must reflect more on what they have learnt and how they are learning. We have found that they do. Using handsets has made it possible to provide an interesting and exciting way for students to gain some insight into their progress and, in this particular case, to develop the critical thinking skills that are fundamental to thinking philosophically.

This case of applying an electronic voting system in lectures might be summarized as follows. A particularly challenging course was selected as warranting the effort and risk of innovation. The absence of a controlled trial and the simultaneous introduction of new teaching techniques as well as several new re-

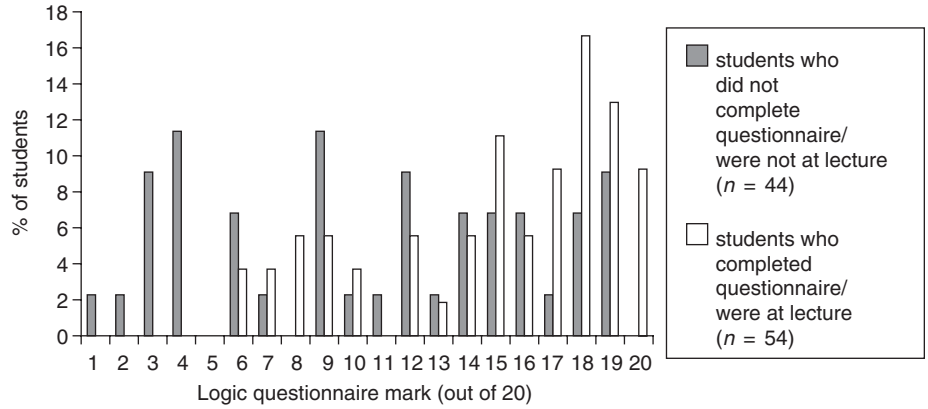

Fig. 1 Logic exam performances for those who were and were not in attendance at the last logic lecture.

sources prevent definitive conclusions from being drawn. However, indications of success include the clear belief by most students in the value of the handsets, and the association of exam scores with attendance at lectures, where the handsets were used. The three mediating objectives in introducing handsets were met (as evidenced for example by the open-ended comments elicited): (i) to make students feel secure enough to answer questions in the lectures because the system enabled them to do this anonymously; (ii) to build their confidence about their learning by their being able to see how they were progressing in relation to the rest of the students in the class; and (iii) to get the students thinking and talking about the subject in a public environment. In addition, as important as the direct benefits to the learners was the benefit of better and much faster feedback to the lecturer on what the students were finding easy or difficult, which allowed timely adaptation of what the class time was spent on. Finally, this case also illustrates the importance of matching the lecturer's method of using the equipment to the particular subject matter. On the one hand, it shows that first-time success can be attainable with little preparation where the lecture plan is pre-adapted: this lecturer did not draw on anyone else's teaching examples, methods or specific expertise in planning how to use the handsets in this course. On the other hand, in her own judgement (rather than her students'), a less careful attempt to use them in another philosophy course, without adapting her use of questions to the different type of subject matter there, was not immediately successful. This only underlines that while the technology may make new successes possible or easier to attain, it is the pedagogical skill with which it is used that determines success.

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