ON THE USE OF A MULTIPLE DISPLAY, IN-ROOM COLLABORATION SYSTEM TO PROMOTE FREE RESPONSE FORMATIVE DISCUSSION BETWEEN LEARNERS AND TUTORS IN SMALL GROUP SEMINARS

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Abstract

Classroom technologies, such as interactive whiteboards and voting systems, have been extensively used within primary and secondary education to mediate local discourse between students and tutors in classroom situations. However, research around the use of such technologies within higher education settings indicates a lower level of utilisation, both quantitatively and in terms of the complexity of pedagogic use for teaching.

The aim of the study reported here is to examine the affordances and constraints of a new kind of technological response system, compared with these more established solutions. The Thunder system, designed for business deployment, allows multiple screens of information to be displayed simultaneously, while input is distributed across a central easel and tablet PCs running client software. We consider whether the modes of free-response interaction supported by the system allow a meaningful cycle of formative feedback to develop between learners and tutors, initiated in flexible ways by different participants within the lesson.

A series of learning scenarios was designed, in which a cohort of students on a masters course, who had an interest in investigating the technological augmentation of learning scenarios, were asked to utilise each technology in turn as a learner, before later reflecting upon their experiences and considering how the technology might be relevant to teaching scenarios. The module tutor was responsible for introducing the technologies and the scenarios and reflected upon the experience from the position of task arbiter.

We adopted an ethnomethodological approach; a student from within the course video recorded the session from several camera angles, while simultaneously taking field notes and participating in the lesson as a peer. A critical incident video analysis technique was used to identify events within the sessions which constituted indicators of rich interaction, both between students and between students and tutors. Additionally, we collected perceptual data from students by conducting a focus group after the series of learning scenarios was complete, and from the tutor by conducting a one-to-one interview.

Findings indicate that the relative affordances of each system are related to different learning scenarios. Interactive whiteboards are effective for whole group teaching, due to the existence of pre-prepared materials, but student interaction with the materials is often constrained by the need to approach the board. The voting systems seem suitable for larger cohorts, but are limited in response due to the dominance of fixed-response or short-response feedback types. Thunder is the most flexible within small group seminars, generating open discussion around both breakout sessions and whole group plenaries through its flexible modes of distributed, free-response input. Students perceived that, using Thunder, it was easier to share opinions and generate debate rather than merely responding to prompts. However, the system was intimidating and significantly constrained by classroom management issues; primarily, this seems to be related to the fact that it was designed for business meetings rather than explicitly for learning.

We conclude that multiple display systems which allow for free response by students, such as Thunder, can provide a feasible and useful way of qualitatively enhancing interactive discussion within technology supported seminar scenarios.

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Keywords

Classroom interaction, interactive whiteboards, voting systems, multiple display, simultaneous information, non-linear information, small group seminars, classroom response, Thunder.

1. INTRODUCTION

Interactivity in teaching is regarded as a critical scenario component, leading to better and more effective learning [8] and promoting creativity among students [14]. As Higher Education institutions commission ever larger numbers of technology-supported learning spaces, the issue of mediating class interactivity using classroom response technologies has become a significant focus of study [7]. While research into the use of both interactive whiteboards (IWBs) [16] and voting systems [6] has found that interactive teaching and learning can be supported and augmented using these technologies, we argue here that new technologies which allow for richer, more free form in-room interaction between learners and teachers can more qualitatively enhance interactive discussion in small group teaching.

Many definitions of classroom interactivity are linked to notions of interactive teaching in secondary education. Teaching is seen as interactive when student contributions are “encouraged, expected and extended” [3] or when reciprocal opportunities for talk are provided, with appropriate guidance and modelling, conducive environments for participation and increased student autonomy [1]. The literature is not uniform in linking interactive technologies with interactive teaching. For example, Smith [23] links IWB use with fast-paced whole-class teaching, persistent initiation-response-feedback (IRF) manoeuvres, and short student responses. Hargreaves *et al.* [10] conclude that IWB use is often “gimmicky” and promotes only surface level interactivity.

It is clear, however, that what constitutes interactivity in technology-supported teaching and learning is still a matter for discussion. Schmid [21], in synthesising the views of several authors, concludes that “interaction” is still thought by many tutors to relate to question-dependent, IRF-based teaching sequences. Greiffenhagen [9] distinguishes between technical and physical interactivity, cognitive interactivity and socio-cognitive interactivity; Smith [22], similarly, divides interactivity into technical and pedagogic categories.

For the purposes of this article, we define interactivity as the process of dialogue around learning which occurs between learners and tutors, and between learners. In our case, this dialogue will be mediated using technology, and will seek to scaffold discussion to promote learning in a manner reminiscent of formative assessment [7]. In a formative feedback cycle, tutors seek to facilitate the development of self-assessment and reflection, encourage dialogue around learning, clarify what constitutes good performance, provide opportunities to improve, deliver learning-focussed information, and encourage student motivation [13]. The thread of commonality in these activities is an attempt to engage students to participate in the learning process, an aim whose success can be measured in the surface- and deep-level interactions in which learners engage as a result [10].

The Thunder system used as the basis for this research is a novel technology, originally developed for business use and appropriated for use in educational settings as a result of capital investment by the Visual Learning Lab, a national Centre for Excellence in Teaching and Learning in the UK. The purpose of the technology is to allow the display of many pieces of information simultaneously within the room, using the concept of “flipchart pages” which are displayed by multiple projectors and controlled by a central easel. The Thunder system also replicates the easel interface on a piece of client software, which we loaded onto tablet PCs, allowing free-form interaction such as the writing of notes, drawing of diagrams and contribution of pictures to occur from the learners' seats.

Our research question is as follows: Can it be demonstrated that a system such as Thunder, which displays large amounts of information simultaneously through multiple screens and allows interaction with the materials from students' seated locations in a free-form way, promote a more rich form of interactivity in small teaching sessions than more established systems such as interactive whiteboards and voting systems. To achieve this aim, we seek to expose students to “conventional” use of these systems and to record the results using video methods and field notes. We then use established definitions of levels of interactive teaching as categories for the analysis of these research materials, in order to show that the objectives of our research question have been met. We subsequently use tools such as interviews and focus groups to establish participant perceptions of why the scenarios developed as they did. In doing so, our objective is to seek an understanding of how the relationships between tutors, learners, technology and natural scenarios are key to enabling the integration of new technologies in ways that enhance learning.

2. INTERACTIVITY WITH CLASSROOM RESPONSE TECHNOLOGIES

2.1 Interactivity and technological mediation

Having defined our model of interactivity as a mediated process of dialogue, it is necessary to consider the kinds of dialogue which might be expected to occur within a seminar session, together with the constraints placed upon those forms of dialogue by the interaction medium. Our aim is to construct an appropriate lens for the analysis of interactions within our small group teaching scenarios, and to seek to provide a basis for understanding the trends identified by the quantitative component of that analysis. Presumably due to the Building Schools for the Future programme [2], which has the aim of ensuring world class learning environments in UK schools through large scale capital investment, research into the use of technology such as interactive whiteboards for teaching has been prominently centred around both the UK and the schools sector [11]. Similarly, literature on the topic of interactive teaching is largely school-based.

An important framework for interactive teaching in schools was developed by Hargreaves *et al.* [10] as a result of a study in which teachers used video stimulated reflective dialogue to discuss their changing perceptions of interactive teaching. The framework identifies nine features of interactive teaching, divided into five surface and four deep level forms. For our work, we adapted the framework in two ways: firstly, to refer to higher education settings rather than schools; and secondly, to refer to scenario analysis rather than curricula (Table 1).

Subsequent work by Esarte-Sarries and Paterson [5, 19] has further evaluated this framework, examining the features of each teaching construct in more depth. Interestingly, whiteboards are frequently used as exemplars of surface-level interaction throughout the work [5]. The authors are keen to emphasise that "surface features address instrumental interests … whereas deep features reflect subtle cognitive and emotional aims" [19], and that both sets of aims are valid facets of successful practice. Nonetheless, it is clear that the expectations for technology by adherents to the framework are relatively limited.

1	Engagement	Maintaining student interest in the teaching session; providing enjoyable experiences	surface forms
2	Practical, active involvement	Constructs requiring movement and practical engagement; "hands on" activity	surface forms
3	Broad participation	Strategies to involve the whole class in activity or in the presentation of knowledge	surface forms
4	Collaborative activity	Student teamwork as the basis for learning	surface forms
5	Conveying knowledge	Constructs involving the transfer of new knowledge, between students and tutors and between students	surface forms
6	Assessing and extending knowledge	Constructs involving evaluating, and building upon, existing student knowledge	deep forms
7	Reciprocity and meaning making	Constructs of two-way dialogue, rather than didacticism, where teacher-student, student-teacher and student-student interaction promotes the construction of meaning	deep forms
8	Attention to thinking and learning skills	Constructs referencing student thinking skills, learning process or activities framing learning	deep forms
9	Attention to students' social and emotional needs and skills	Constructs teaching or addressing the emotional needs and social interests of students	deep forms

Table 1. Interactive teaching constructs (adapted from [10]).

In terms of technical mediation, student responses can be divided into two types: fixed-response, where students choose from a limited set of pre-configured answers, and free-response, where students construct their answers freely using a set of basic tools designed to assist the construction process [25]. Tsintsifas [25] has argued that free-response question types provide a more appropriate mechanism by which to assess higher order cognitive functions. Additionally, both Tsintsifas and Swan [24] argue that dialogue around problems may be constrained if unnecessary notations are introduced, since interactions between students and tutors may come to be focussed on the notation itself, rather than on the underlying concepts. Similarly, Higgins *et al.* [12] argue that it is necessary to change the response medium itself to match the kind of interactions which are desired rather than carefully constructing questions to overcome the limitations of a simpler medium. Due to the fixed-response nature of our chosen voting system technology and the fact that both IWBs and Thunder constitute free-response systems, we were keen to examine the impact of such notions on in-room response technologies, as opposed to the areas of curriculum design and e-assessment where the notions were developed.

2.2 IWBs and voting systems

Much established research focuses on the use of interactive whiteboards in school education; a review of the literature is provided by Higgins et al. [11]. IWBs are seen to have a number of benefits driving adoption: they make it easier to incorporate many forms of media coherently into a lesson; they assist the process of creating attractive classroom resources for learning; they capture and hold the attention of learners; they enable teachers to represent abstract concepts in novel, interesting ways; they can encourage resource sharing if connected to an intranet; and they correlate well with established modes of whole-class teaching. Related disadvantages are broadly categorised as practical, logistical or financial. Despite the affordances of the technology, Higgins et al. conclude that “it is the skill and professional knowledge of the teacher who mediates the interaction of the pupils” which is critical to the enhancement of learning.

A corresponding literature review of voting systems is provided by Fies and Marshall [7]. Major benefits of the systems include greater student engagement, understanding of complex subject matter and student enjoyment, together with increased student awareness of individual levels of comprehension, increased teacher insight into student difficulties and heightened discussion. However, the authors note that studies of voting systems often lack rigour, address individual rather than small group usage, compare voting system usage against control scenarios which lack true equivalence, and rarely describe conditions of use such as formative assessment or scaffolded instruction. The authors conclude that there is a need for research which explores conditions for use of voting systems across diverse settings and pedagogies.

Finally, a small but noteworthy strand of work seeks to understand the affordances of using the two technologies in tandem. Schmid [21], for example, presents a study of interactivity in the classroom using an IWB in conjunction with a voting system in a University setting. Using ethnographic research instruments such as classroom observations, video recordings, interviews and questionnaires, Schmid was able to conclude that the combination of IWB and voting system use had several pedagogical benefits, including “adding value” by encouraging the participation of shy and self-conscious students; allowing participants to gauge the opinions of others anonymously; and breaking the pattern of “teacher talk”. Schmid, however, does not attempt to identify which of the perceived advantages from the study were gained as a result of the individual technology components, and which were gained as a result of the juxtaposition of the two.

2.3 The Thunder system

The PolyVision Thunder system [20], created as a tool for corporate meetings, is marketed on the basis that it is “the future of collaboration”, promoting advanced information exchange based around human centred design principles. Since Thunder has not previously been the subject of published academic studies related to learning and teaching, and is not widely deployed in educational settings, it is necessary to rely on corporate materials and technical articles to provide a description of the system here.

Figure 1. The Thunder system and a client PC

Marketed as “walls filled with virtual information, there to be studied, absorbed, shared, emailed or stored in an instant” [20], the Thunder system consists of a central easel designed to look like a “flipchart”, with digital versions of pens, erasers and other input devices, and a series of projected screens designed to mimic the effect of flipchart pages being “hung” along a wall. Figure 1 shows the easel and the first two sets of projected screens in the laboratory classroom used for this study. The easel can be rotated into portrait or landscape formats, allowing the projected pages to become either larger or smaller to match the aspect ratio of the documents. PolyVision’s characterisation of the system involves three “levels” of use [20]. The first level is to use the easel and screens to create an immersive, in-room experience. The second level involves bringing in remote participants through integrated telephone conferencing and laptops connected using client software. The third level is to connect two or more Thunder systems together for ‘seamless’ collaboration across remote locations.

The client software, which we installed on a series of laptop PCs with pen tablet input, is also shown in Figure 1. The software replicates the display of the easel on the laptop and allows students to either view the session remotely or, if they have been given appropriate permissions within the session, to edit the materials using the same tools as a user standing at the easel.

Our study used a hybrid model, combining the first two PolyVision levels of use to create an immersive in-room experience in which students could contribute their thoughts to the system using the client software from their desks. Although the Visual Learning Lab’s capital investment programme did indeed fund the purchase of two separate Thunder systems [17], we did not focus on collaboration across remote locations within this study.

3. DESIGNING THE INTERVENTION

3.1 Instruments

For this study, we utilise two primary research instruments. Our first research instrument is video footage, which we analyse according to the interactivity framework in Table 1 to produce both quantitative and qualitative results. Our second research instrument is a focus group, which we conducted using a subset of the student participant group in order to gain perceptual insight about the relative student reactions to the interactive technologies.

The use of video to support qualitative research is recognised to have several key affordances. Derry [4], for example, points out that “because video enables the capture of detail and complexity that can be viewed and reviewed from multiple analytical perspectives by multiple researchers, video data affords the in-depth, detailed exploratory analyses that qualitative studies provide”. Indeed, the advent of videotaping as a research instrument has long been recognised to have added a new dimension to the study of human behaviour more generally [18]. However, the use of video certainly carries disadvantages in comparison with other forms of data gathering; in terms of validity, particularly, the effect of video footage on contextual observation is profound [18]. Despite these limitations, the potential for video research remains considerable. Derry [4], for example, argues that, with careful standardisation, video cases can be constructed which are representative, embedded, reflective, scholarly and which can study both verbal and gestural data.

Within our study, we used multiple camera angles in an attempt to overcome problems of contextualisation. After the data gathering process was complete, the video footage from the three angles was synchronised (using Avid Media Composer software), to produce research data as illustrated in Figure 2.

Figure 2. An illustration of the synchronised video footage used within the study

We analysed our video research data in two distinct ways. Firstly, we analysed each of the three scenarios separately according to each interactivity category. Each time an event occurred within the footage which fulfilled the category criteria, we noted the start and end time of the event to gain an indication of the duration of time over which the criteria was met. The footage was analysed by two raters, who initially analysed separate sections before crossing over to check reliability. A subsequent meeting was held to discuss inconsistent ratings, which were eventually re-categorised by mutual agreement. The second type of video analysis with which we engaged aimed to identify good examples of the interaction types. Unavoidably, this process was subjective; initially, one study researcher was responsible for identifying the categories, which were discussed at a subsequent project meeting.

Our second main research instrument was a focus group. The focus group was a semi-structured discussion which aimed to elicit student responses to the technologies in an informal way, to provide perceptual supporting evidence for the trends uncovered by the video analysis. The focus group was audio recorded and transcribed, with subsequent research working from the transcript to identify student comments related to our study outcomes.

3.2 Environment and context

Since a focus of this study was to identify the ways in which tutors and students might use the three technologies in a naturalistic fashion, we decided against the idea of imposing formal learning scenarios upon the student group based upon research evidence. Indeed, this would have been an impossible task in the case of Thunder, since no prior academic research has investigated the use of this system to support teaching and learning. Instead, we took advantage of the fact that the tutor of the group was an established user of educational technologies, and allowed the scenarios to develop in an exploratory, rather than prescribed manner. Although we were interested in comparing the levels of interactivity facilitated by the systems, beyond this our study was more interested in the generation of hypotheses than in their examination. The laboratory classroom in which the students used the voting system and Thunder was arranged as illustrated in Figure 3. The students were seated in groups around flexibly arranged desks, arranged in such a way that the students were able to observe the information on the Thunder easel (in the corner) and on the projected screens. Figure 1 also illustrates the position of our three video cameras and their field of view. Cameras 2 and 3 had a fixed field of view, while camera 1 was focussed appropriately by an operator. The interactive whiteboard scenario was played out in a different classroom, whose layout is illustrated in Figure 4.

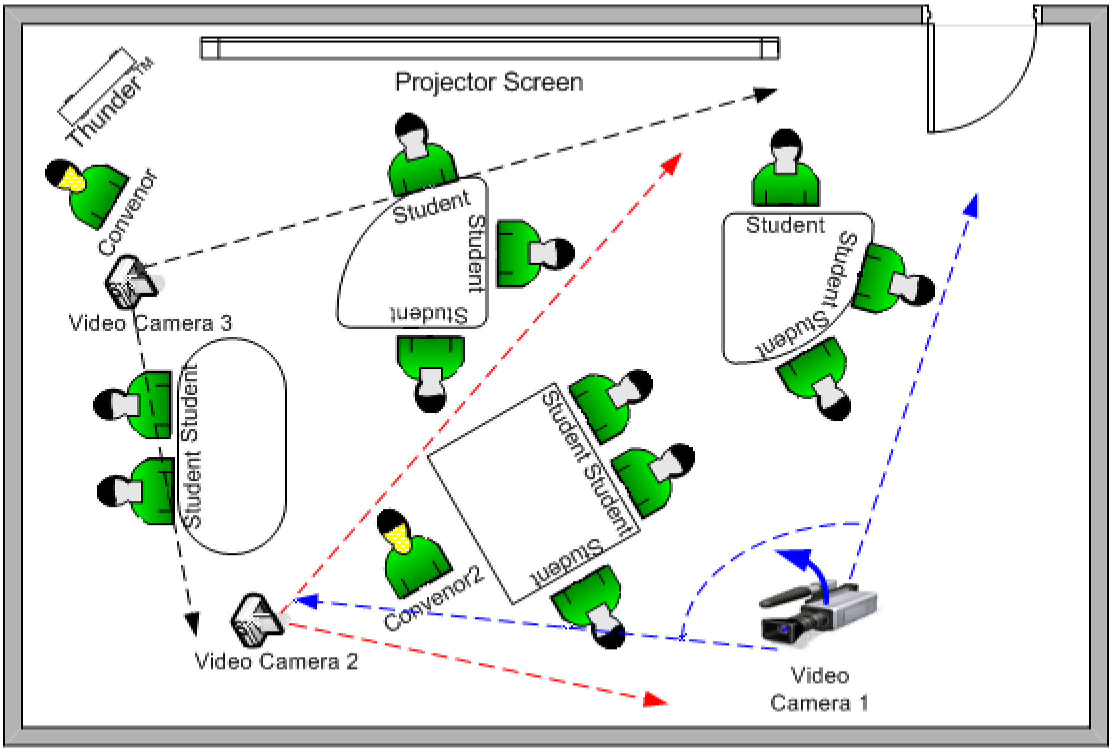

Figure 3. The Visual Learning Lab laboratory classroom. Scale 60:1 approx

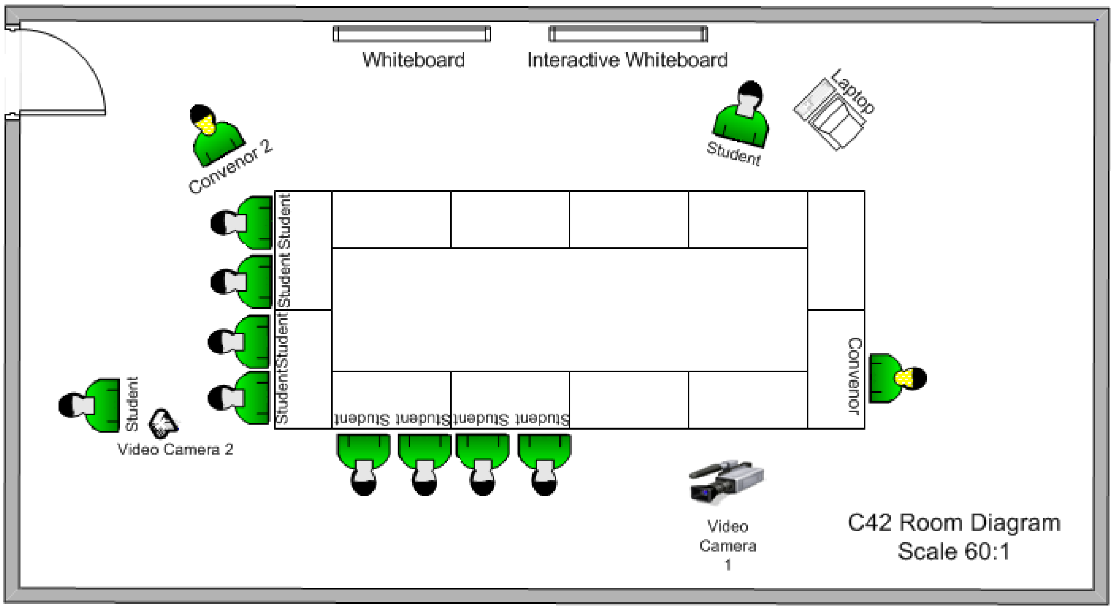

Figure 4. The classroom used for IWB usage. Scale 60:1 approx

4. FINDINGS

4.1 Video

4.1.1 Overview

After combining the amount of time within which the category criteria for each form of interactivity was met, we needed to take into account the fact that the three systems were not used for the same amounts of time. Within the sessions, which were controlled by the course tutor, The IWB was used for approximately an hour, while the voting system was used for slightly longer than 10 minutes and Thunder for slightly less than 50 minutes. The values presented in Figures 5, 6, and 7 are, therefore, represented as percentages of time, to allow comparison to be drawn in subsequent discussion.

The broken lines in each case represent the mean averages for the surface and deep level interactions respectively. These averages are summarised in Table 2.

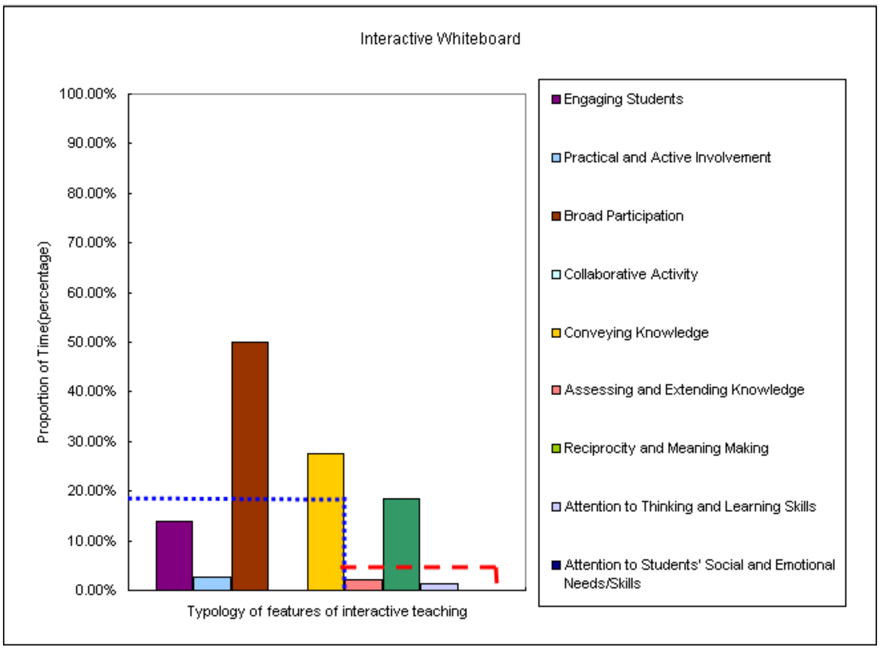

Figure 5. Percentages of time vs. typology for IWB

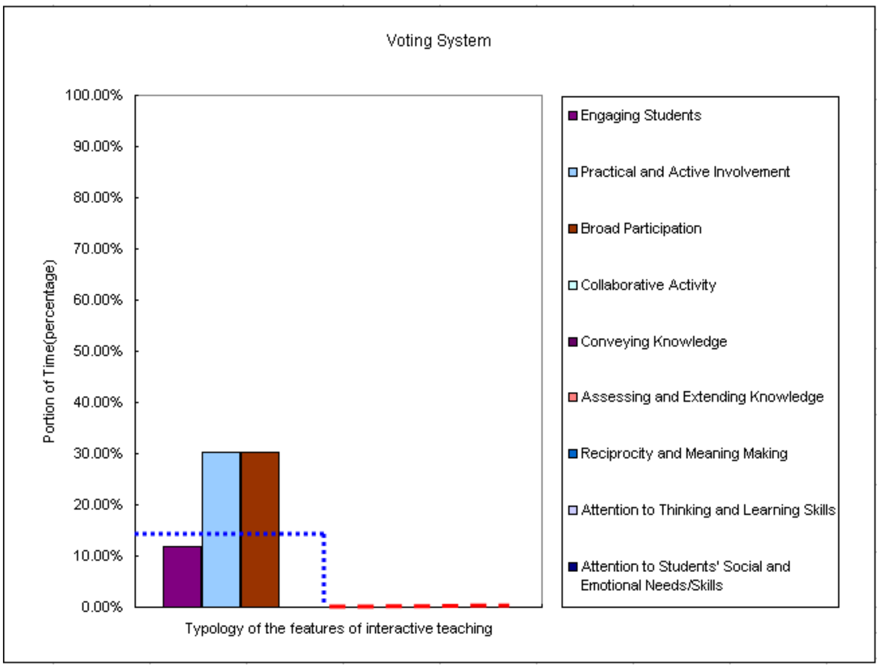

Figure 6. Percentages of time vs. typology for the voting system

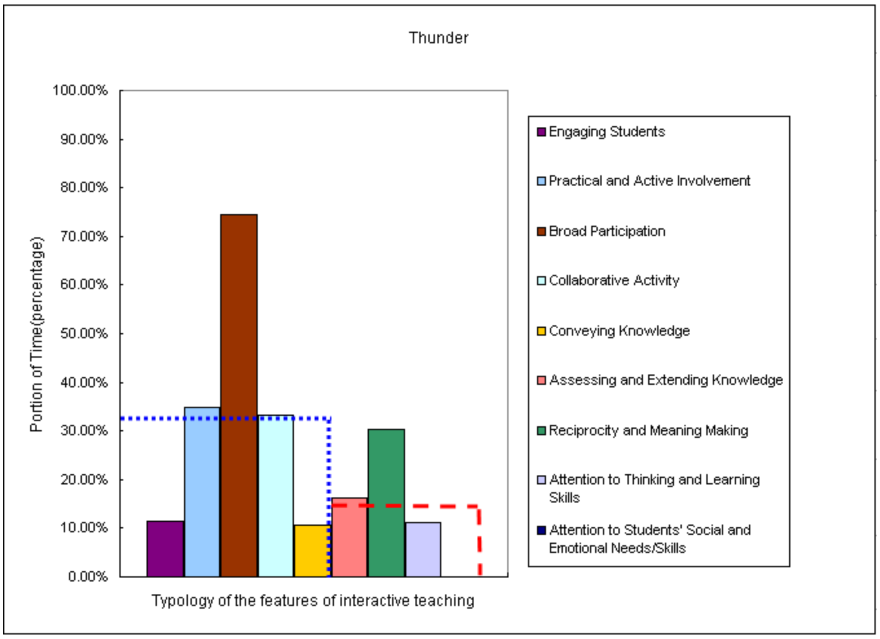

Figure 7. Percentages of time vs. typology for Thunder

	IWB	Voting system	Thunder
Surface features	18.81%	14.43%	32.92%
Deep features	5.49%	0.00%	14.41%

Table 2. Averages of surface and deep feature category criteria being met for each system

4.1.2 Critical incidents

Important comments about the interactive whiteboard during the session can be grouped according to two broad categories: interaction with the materials in response to circumstances, and the differences in levels of usage according to teacher enthusiasm, technical skill and experience.

For example, a student commented during the IWB session that the technology offers more chance for interaction with the materials than simply a projected presentation: "*The projector and laptop is just projecting something you have produced. There is no way that […] particularly, children can actually contribute to the session. So all you're doing is 'I have done this, look at this!', that's why I'm saying. you can't say, 'come out, tell me what do you think? 'What do you think' is good about the IWB…*". Similarly, a student commented that the IWB "*really brings a lesson live. It's exciting, it's interactive, everybody can see it clearly. They can come out, they can take part of it...*".

On the topic of teacher experience, it was observed that: "*I think the key point for me is what xxxx said a couple of minutes ago was about people's learning how to use it actually. I guess people do that with different speed, don't they? How would you go about encouraging somebody who was perhaps slow to explore the possibilities? To just... kind of push him a little bit and develop with it?*". Comments about typical IWB usage reflected the perception that many teachers do not utilise the technology to its full potential. In this case, a tutor commented thus: "*xxxx is right, although actually I wasn't thinking that. I was thinking about the teachers I knew who exist, who simply use IWB as somewhere is expensive to shine data projector. Your answer was perfect when actually, enabling getting children out and doing things where other children can see it. That's really the key. But it's interesting that for a list, a number of teachers, they don't get to that stage. It's somewhere to shine the PowerPoint*".

The voting system was used within the sessions for the shortest time of any of the technologies. Criticisms of the system were that it is restricted to asking a very limited range of questions: "*You cannot really interact with students and teachers (with Voting system) because you can only say yes or no or just choose one of the options the teacher gives. But you can't give your own answer and you can't say why you did you choose that*". Other students speculated that the system could be used as a springboard to consult more deeply about student thoughts thus: "*That's how we use it – ask opinions. Schools send evaluation forms to children. Every school has to ask pupils' opinions on the school. Every year we have to ask what they think about it, so we give them that and they vote*".

Comments about Thunder were mixed, with positive comments focussing on the ability of the system to support group work: "*it is possible have people not in the room joining in, so in another class, another part of university or even another country. They could be sending across their ideas and so it is not necessary system that has to work in a single room. Do you think is something more convenient use of? As support for group work? … The way we try to integrate your different thoughts about this to the share space, is it worth it?*", to which another student responded, "*Yes..because you can present each group's result what have been discussed in the group and share…*". Many comments took the form of questions to the tutor about the facilities of the system; this is to be expected since the system has not been widely deployed and, therefore, would not have been encountered previously by the students.

Negative comments derived from the fact that the procedure for drawing on the same flipchart page at the same time worked idiosyncratically: "*So [we] cannot even write at the same time. Until they bring out this IWB which more than one person can do it at a time […] you've got to take it in turns once at a time. Suddenly occurred to me, but if you can write, what is the purpose of sort of being able to access at the same time if it is not functional….*". The session tutor agreed with this sentiment, and further pointed out the limitation that, from his perspective he could only interact directly from the easel rather than the projected screens: "*It's not allowing me to treat it as a single service. You feel this screen ought to be available to be written, take many pen to many projector services and do something that could be saved. So we can manipulate the whole thing at one time rather than being able to operate separately*".

4.2 Focus groups

It is a fair approximation to say that the comments made by students within the focus group were broadly in line with their stated opinions during the session itself. For reasons of brevity, therefore, we will concentrate on comments regarding the Thunder system. First and foremost, opinion was divided by those whose first impression of Thunder was that the system was intimidating, and those who thought the system refreshingly simple to use. One student within the focus group embodied both points of view simultaneously: "*It's intimidating. Basically the screen is quite simple: I mean there are not many options – at least not on the screen that we saw. You can write and there are some options there to use slides but, like everything, it takes time to get used to it, I think, but it did not seem very complicated*". Confidence in using the system seemed to grow throughout the session: "*It was the first time that we were using it all together. We had our laptops connected to it so everything was a new experience; everything we did was our first time doing it. We got used to it by doing it*".

Students felt that they were able to contribute significantly to the session from the tablet PC: "*Because we were separated in groups and each group discussed a topic and exchanged some ideas and views and then we started writing our ideas and then those ideas were seen by the other groups so I think it was something very useful and because all the groups exchanged their ideas we had a good interaction with this process*". Similarly: "*Well since everybody posted their ideas you could comment on them; accept them; reject them or challenge them and they had to explain again so a discussion was generated from those ideas so perhaps our understanding of the subject was a bit better and we learnt from those. They had new ideas that they could share and everybody had different experiences or backgrounds so you can always get something new from other people and the Thunder system is a good way to expose these ideas*".

Students also felt that the Thunder technology made the session "*less tutor led*", but that the tutor, ultimately, still had to "*control what had to be displayed*". Another student, similarly, commented that: "*I think it was a more open discussion because at the start we discussed in our groups and then, after the display of our answers, we had a general discussion in the class – in the whole class setting*". Negative points regarding Thunder centred around classroom management issues: "*The problem with Thunder is that you can only work at one stage at a time: if you have different slides you can only select which one you are working on and you can write on that one only. If you are working on slide 3 and you want to comment or highlight something on slide 5 then you need to change to slide 5 so you can modify it t[…] So you had many groups working at the same time on different slides and that is the disadvantage of Thunder because I don't know if they can […] have different groups working on [the same] slides*".

Interestingly, students also thought that it might be useful to use the technologies concurrently: "*If you use it as a combination then I think it is more useful […]the teacher would use the SMARTboard; the groups the tablet PCs and then the voting system*".

5. DISCUSSION

The typology of interactive teaching was specifically chosen as the lens through which this study was conducted because it is a yardstick by which interactive whiteboards have been previously seen to fail. From a scientific perspective, it was good that we were able to replicate established results from the literature in relation to the interactive whiteboard and voting technologies; this provides a measure of informal hope regarding the validity of our results for Thunder, which cannot be compared with established studies. Interactive whiteboards were effective at catering for surface features of interaction, but less so when the deep features of interactivity were examined. IWBs were also seen as suited to whole group sessions rather than promoting interactivity between students, although the interaction between individuals and the materials facilitated by the system is regarded as important for teaching and learning. The voting system scored particularly poorly in our quantitative analysis. This may be due to the shortness of time for which the system was used, or due to the inherent lack of sympathy which many learners seems to have with the system. Interestingly, the students chose to discuss the three technologies using the Thunder system itself, which may result in complex cross-pollination effects for our research instruments.

The Thunder system scored relatively well in the quantitative analysis. We were encouraged by the fact that the system significantly outscored the IWB within the deep interaction categories; we had not anticipated, and were surprised by, the fact that Thunder also scored better on surface level interactions. It must be noted, however, that student opinions of the system were divided. While students liked the level of interactivity afforded by the system, and seemed to value the free-form nature of the interaction which they could be engaged in, many students found the system both intimidating and infuriating (especially in the way the system enforced interaction with the client program). It is clear that these issues will need to be addressed if significant penetration into teaching and learning institutions is to be achieved by the system.

6. CONCLUSION

From the quantitative analysis and from the focus groups, it is clear that there are both real and perceived advantages and disadvantages to each of the three systems we compared. While the Thunder system has been successfully demonstrated to have promoted more interactions, at both a surface and deep level of interactivity, than either of the other two systems in our comparison study, we note significant obstacles to adoption. Thunder, however, does seem to be the most flexible technology within small group seminars, generating open discussion through its flexible modes of distributed, free-response input. Students perceived that, using Thunder, it was easier to share opinions and generate debate rather than merely responding to prompts. The main conclusion, therefore, must be that multiple display systems which allow for free response by students, such as Thunder, can provide a feasible and useful way of qualitatively enhancing interactive discussion within technology supported seminar scenarios. However, such systems must in future be designed first and foremost for learning, rather than under the assumption that a corporate meeting tool can be adopted into education with ease.

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