Logic Gates & Feedback: Towards Knowing What's Going on in the Electronics Lab

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Abstract. We describe preliminary work using participatory design methods with teachers looking at how technology might be used to improve teacher awareness of individual students' comprehension of key concepts, progression through activities and engagement during classes. We are exploring the use of mobile devices and Learning Management Systems to support face-to-face teaching.

Here, we report pilot studies in which we used a class set of tablet PCs and online resources to capture live data about learner progress, comprehension and attitudes during hands-on electronics classes. We report findings in terms of teacher, learner, technical and pragmatic issues. Results suggest our approach has the potential to improve teacher awareness of what is really happening in a session and to enable teachers to make suitable adjustments in real-time. However, very efficient user interfaces and appropriate data logging, filtering and representation will be required in order to make 'live' information useful to and usable by teachers in the classroom. These studies enable us to make specific suggestions about the features that would need to be realised in future system versions.

1. Introduction

1.1 Objectives

Teachers frequently wish to and are increasingly under pressure to deliver individualised learning experiences in the classroom [1]. One strategy employed is to assign activities, tasks or projects for individuals and/or small groups to work through independently and at their own pace. However, this mode of operation places a substantial burden on the teacher in terms of monitoring and responding to each individual's progress, comprehension and engagement. Supporting such requirements and providing self-paced individualised learning have been key motivators for a great deal of the work in the field of educational technology design and particularly Artificial Intelligence for Education, which has often aimed to provide 1-to-1 intelligent tuition through the use of technology, for example [2, 3, 4]. The work described here is similarly motivated but differs from much of this work in three ways:

- Firstly in approach: We aim primarily to support the teacher rather the learner. By reducing the classroom management and monitoring load whilst improving the teacher's awareness of each individual's progress, comprehension and engagement we aim to enable the teacher to spend more time attending to each individual's needs, adjusting their learning experience as necessary.
- Secondly in viewpoint: We envisage learning happening primarily during the face-to-face interactions between learners, between learner and teacher, and between learner and other classroom resources **not** through interaction with the system.

- Thirdly in context: The learning activities themselves for the most part take place in the physical space through discussion, interaction with laboratory equipment, circuit boards, maps, etc **not** necessarily in 'virtual space' on a computer. Understanding the contexts learning takes place in and the interactions with the resources (human and other) available in these contexts are of primary importance.

1.2 Mobile Devices in the Classroom

Mobile computing, wireless networks and digital resources enable us to capture, collate, and process live data from numerous learners while allowing them to interact and move around the classroom (or elsewhere) more or less naturally engaging in traditional learning activities. Many researchers [5, 6] have realised the opportunities afforded by such technologies both to improve the efficiency of face-to-face learning experiences and to enable hitherto complicated or impossible interactions. For example, classroom-voting systems can enable teachers to ask comprehension check questions to entire classes and view individual responses without forcing individuals to reveal their understanding (or lack of it) to peers [7], similarly handheld devices can be used to post anonymous questions live during a session [8]. A limitation of classroom voting systems is that they typically have no screen so presentation of information through the individual device is not possible. This limits the options for using such systems to present individualised instructions and to allow individuals and pairs to progress through sequences of activity at their own pace.

In the domain of online learning, Learning Management Systems (LMS) (e.g. Moodle, LAMS, etc…) have been developed to taken on a great deal of the teacher's management load making it relatively easy to design and deliver online courses and monitor and interact with individual learners at a distance. Indeed, many LMSs also integrate the tools to support voting and question asking (as mentioned above) and many other kinds of learner-learner and learner-teacher interaction. However, these are most often employed asynchronously and not in support of live, face-to-face teaching, a context in which demands on the teacher are quite different. Our interests here are in understanding: whether by providing teachers with live access to feedback from LMS activities we can help teachers to more effectively monitor learner progress through face-to-face physical space learning activities; what monitoring tools are required by teachers in-session to do this; and what are the potential costs and benefits both to teachers and learners in these kinds of teaching and learning contexts? This work is an initial exploration of the use of mobile devices and LMSs to support live face-to-face teaching in the specific context of practical electronics laboratory sessions. However, we believe some of the issues and requirements this work begins to elucidate will prove of interest to educational technology researchers. Here we report our design process, initial study and results in terms of learner and teacher needs, and technical and pragmatic issues.

2. Studies

2.1 Design Process

We introduced 2 teachers to the kind of experience we were interested in exploring through conversations around some possible usage scenarios and demonstration of software on a tablet PC. Specifically, we talked them through example uses of individual Tablet PCs to support classroom voting, anonymous question and answer and structuring of lesson content and demonstrated related features of the Moodle learning environment. We asked them to reflect on the opportunities afforded by this technology and to identify a suitable opportunity and subject domain to trial the technology in. Having identified a series of electronics sessions on logic gates as a suitable opportunity, we observed one session taught in the usual way with no additional technology. Then through a further series of conversations we established the teachers' initial requirements in terms of the kinds of question they would want to ask individual learners and possible variations in the session structure and iteratively refined prototype resources to support these using Moodle.

2.3 Why Moodle?

Moodle is a very popular, free Open Source course management system created with course designers and learning communities in mind[1]. Moodle was chosen as the learning environment within which to create the course material for pragmatic reasons. A Moodle server was readily available at our institution, we were familiar with course construction using Moodle and we wished to start creating and refining the electronics course as rapidly as possible in order to support our iterative development methodology. Although our primary focus was on supporting face-to-face teaching we also wanted the online material used in class to be available and easily accessible to students and teachers from home. We are interested in the potential for learners to revisit material from class at home and possibly to involve parents and/or others in conversation around this.

2.2 Learning About The Electronics Sessions

Our teachers wanted to trial the technology in a series of intensive hands-on electronics classes they run as part of the programme for Gifted & Talented teenagers from local schools at our University. These sessions were chosen both for practical reasons (timing, location, easy access to technology, repeated with several groups) and for their pedagogic appropriacy. During these sessions students learn about logic gates through a series of practical activities and pairs work through a number of circuit board design problems at their own pace. The teachers explained that while they consider it very important to assess each individual's comprehension of key concepts at various points in this session, it is often difficult for them to do so as learners work in pairs or small groups, and therefore it is quite possible for weaker members to hide. Also, these teachers often don't have previous knowledge of these particular learners as they are drawn from various local schools. During our observation session we noted that it seemed very difficult for teachers to keep track of how far and how successfully any particular group had progressed through the series of tasks assigned; teachers often relied on asking the group whether they had done activity X or Y yet and whether it worked. Comments such as "Why didn't you tell me you had finished?" were also quite frequent. These teachers later confirmed that it was sometimes difficult to be sure about who had done what and how successfully in the session. We also noticed that open questions to the group as a whole, such as "Are you finding it challenging?" and "Are you enjoying it" were quite frequently used in an attempt to assess engagement. In follow up conversations the teachers stated that they were particularly concerned that learners should find these sessions both challenging and engaging and that they attempted to vary pace and direct activity so as to achieve this. However, they were aware that open questions to the whole class were unlikely to elicit the full range of individual opinions.

2.3 Initial Requirements From The Teacher Perspective

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[1] Moodle learning management software http://moodle.org/

Specific initial teacher requirements drawn from the design work described in the previous section give rise to our key objectives of improving teacher awareness of each individual student's comprehension of key concepts, progression through activities and engagement throughout the session. Teachers wanted:

- To be able to view individual answers to pre-prepared key concept checking questions at appropriate moments during the session.
- To be able to ask spontaneous questions to the whole group and see each individual's answer without it being revealed to their peers.
- To be able to see each group/individual's progress through the activity sequence.
- To see answers to questions aimed at assessing individual engagement and challenge at intervals throughout the session.

Teachers were also interested in having a lasting record of session activity and question responses and ideally representations of the circuits learners built as solutions to design problems.

2.4 Session Equipment

The standard equipment used in these sessions is a PC and data projector for full class display of teacher presentations, and a decision module circuit board and wires (see figure 1), battery pack and an electronics design challenge booklet for each pair of learners. For the 'enhanced' sessions we built and iteratively refined a Moodle course in dialogue with the teachers (see figure 3). This contains instructions for a number of activities (usually given orally by the teacher or written in the design challenge booklet) and incorporates comprehension-checking questions, spaces in which to provide written descriptions of circuit board design solutions and questions intended to assess engagement (see figure 4). The course also linked to an online decision module simulator that enables learners to test circuits by drawing wires between virtual inputs, logic gates and outputs (see figure 5). For example, if a wire is drawn from the push switch to the NOT gate input and from the NOT gate output to the lamp the lamp goes on. Each learner was provided with a Tablet PC (see figure 2) and accessed the Moodle course over a wireless network in the classroom. Teachers did not have their own laptops, rather the researcher used a laptop, which was moved around the classroom, and the administrator interface to the Moodle course to present live activity data and question answers to teachers during the session and as necessary to help them access and interpret this data.

2.5 The Sessions

We ran a two and a half hour session twice with 2 teachers, with between 9 and 12 learners per session. Two researchers were present at both sessions to observe, to assist with technical issues, and to facilitate teacher access to and interpretation of the Moodle activity log data.

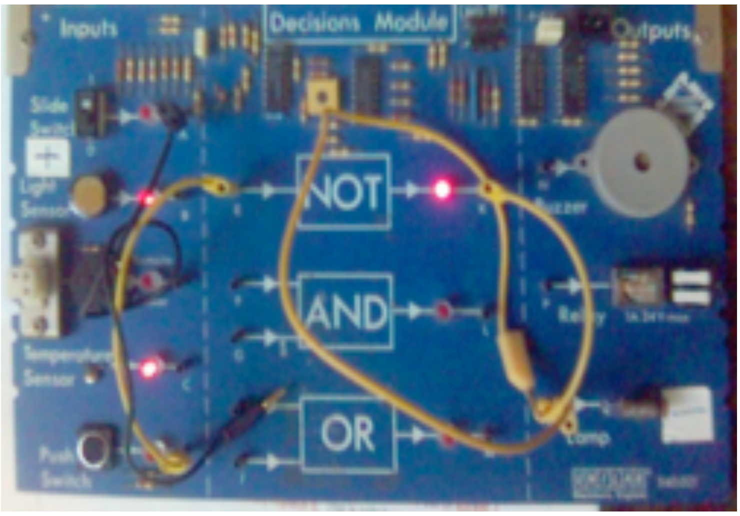

Figure 1. Decision Module Circuit Board

Figure 2. Tablet PC

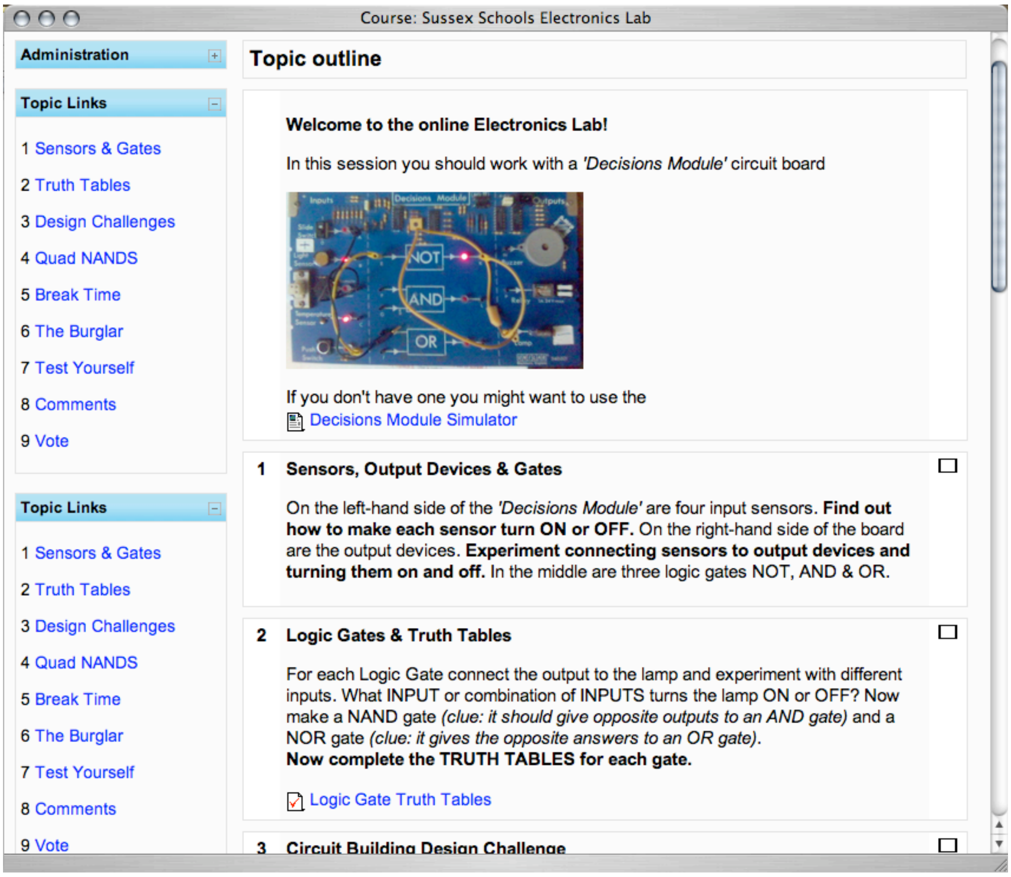

Figure 3. Moodle Electronics Course Screenshot
(see http://www.informatics.sussex.ac.uk/courses/ile/moodle/course/category.php?id=8)

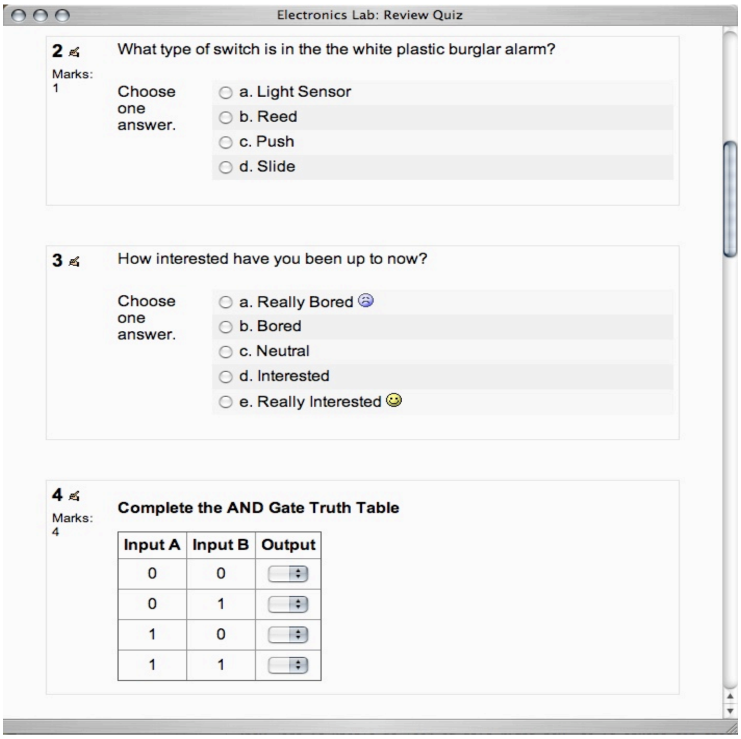

Figure 4. Example questions from one of the activities learners completed during sessions.

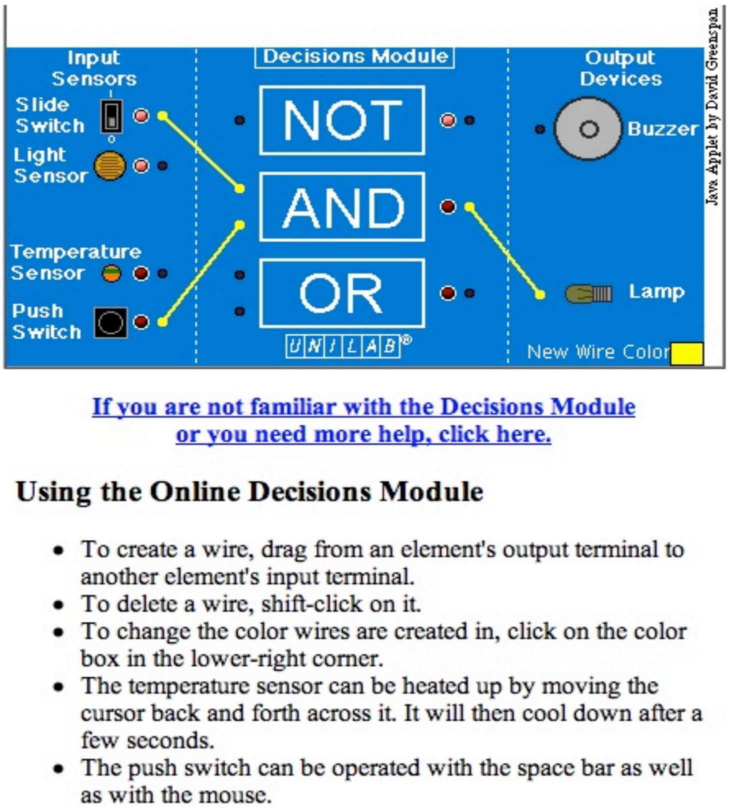

Figure 5. Screenshot of the Decision Module Simulator with 3 wires drawn (yellow lines)
See http://diamond.lexingtonma.org/coalition/Decisions.html

For most of the session, learners work in pairs at benches to investigate the functions of the logic gates and solve electronics challenges. However, the teachers also bring the whole group together from time to time around a table to introduce sections of the session, to demonstrate activities and to conduct whole class discussion. For most of the session learners are free to move around the laboratory and interact with the teachers, other groups and their partners. The teachers move around the classroom monitoring pair-work and individual activity. Often interactions both between learners and teachers are prompted by the practical activities they are engaged in and reference the physical circuits they are building and/or the written instructions for the activities. Teachers also frequently ask individual or pairs to describe the circuits they have built and to answer questions designed to check understanding of key concepts or to prompt reflection on their current understanding.

3. Findings

Our findings draw on initial analysis of the Moodle logs, observers' notes and teachers' reflections on the sessions elicited in conversations following the trials. We also draw on our observations of the same electronics sessions delivered without the use of Tablet PCs and the Moodle course. More detailed analysis of log files is ongoing. Here we report findings in terms of interaction, teacher, learner, technical and pragmatic issues.

3.1 Interaction:

- Patterns of interaction between teachers and learners and learners and learners were similar across the sessions with and without Tablet PCs and Moodle. Teachers and learners still moved around the classroom freely and interactions between teacher and students were largely focussed on discussion of the physical circuits being built or questioning to check understanding. However, we heard less comments of the 'what do I have to do now' and 'why didn't you tell me you had finished' type and some reference to instructions, questions and feedback provided through Moodle on the Tablet PCs.
- Patterns of interaction between learners, teachers and equipment were different as a result of the additional equipment. In sessions without the Tablet PCs we had seen some situations in which pairs took it in turn to build circuits with the partner who was not building the circuit apparently not being engaged. Teachers also cited this as a concern. In sessions with the Tablet PCs, we sometimes saw one member of the pair building a circuit while the other was engaged using the PC. We also saw pairs talking together about answers to questions on the Tablet PC, for example about completing logic gate truth tables. This is equivalent to their talking about paper and pen drawing of logic gate truth tables in the sessions without Tablet PCs. The difference is that feedback on truth tables was provided on demand by the Moodle learning environment as opposed to having to call a teacher over or wait for a teacher to check the truth table.

3.2 Teachers:

- were very enthusiastic about seeing summary and individual results from concept check and engagement questions live in class, and to some extent they gained the ability to adjust their teaching in response to this information as indicated by decisions to bring the group together for a whole class discussion after viewing results to a Moodle question about individual's perception of their own understanding.

- required substantial assistance in finding and interpreting Moodle question answers and log data live in sessions. This was particularly the case in terms of understanding student progress through the activity series.
- suggested simplified views on the data they would like such as "a screen showing who is ahead and who is falling behind" or "just highlighting who hasn't got it".

3.3 Learners:

- were successfully able to co-ordinate use of individual Tablet PCs and electronics circuit boards and did not appear to be substantially distracted by the technology.
- were reluctant to write anything more than minimal explanations of their circuit board solutions to design problems and sometimes appear to have attempted more problems than they wrote solutions for. They consider the task done when they have built a working circuit and the teachers we worked with also considered the building of the working circuit important. However, teachers found it difficult and time consuming to follow student wiring and impossible to 'inspect' the wired answers to previous practical questions as these were dismantled in order to move on to the next problem.

3.4 Technical and Hardware Issues:

- A consistently reliable wireless network connection for every device is essential. Losing the connection resulted in substantial delays for individuals and slowed the overall pace of the sessions. As a result of unreliable wireless access it was quite often necessary for learners to switch to using fixed PCs and/or to share computers during the sessions.
- In this context smaller individual devices would be more appropriate: for several reasons there are space issues on lab desks already crowded with electronics equipment; smaller screens would provide greater 'privacy'; mobility is important as individuals regularly move from a whole class space around a table to small group spaces on benches and sometimes change groups during sessions; and individual answers rather than a (mostly) agreed pair response can be obtained by teachers. It was a noted teaching concern to avoid a quieter student being carried along by a more able peer without the teacher realising.

3.5 Pragmatic Issues:

- The incidental provision of a circuit board simulation on the course Moodle page proved useful: for whole class wiring demonstrations using the data projector, as a replacement for hardware circuit boards when these fail, which is fairly frequent and occasionally for one member of a group to try out wiring ideas on while the other works with the hardware board. These teachers found it very useful to have the student's name clearly visible on the student's Tablet PC (at the top of each Moodle page) as they did not always know students' names. This allowed mental notes of faces, names and attainment level to be maintained and adjusted dynamically, and ideally the feedback teachers see on screen should also reinforce this information.

4. Discussion and future work

We have reported initial work on integrating a learning management system with mobile technology to support problem-based, hand-on activities. This work leads to a number of suggestions for how to better support classroom teaching using mobile devices. However, this work is at an early stage and we have not yet had the opportunity to evaluate any of these suggestions. Our design methodology of involving teachers through scenarios, prototypes and classroom evaluation has been very successful in drawing out significant issues for the use of handheld devices to improve classroom teaching in this context. This has led to concrete suggestions for features that we intend to design and realise in future work, some of which we believe will be useful more generally in face-to-face teaching contexts, e.g:

- An interface to live log data specifically designed to meet the needs of a teacher actively engaged in a face-to-face session. This will provide easy navigation to significant summary information predefined by teachers as well as an overview of who is where in terms of progress through a schedule of activities.
- Automated teacher alerts for significant events e.g. apparent student inactivity, finishing of activities, incorrect answers to comprehension check questions, etc... These can perhaps be provided by agents analysing live log data.
- An easy way of recording 'wiring' of solutions to design challenges, perhaps through drawing circuits as opposed to providing written explanations or more ambitiously through automated logging of the actual circuit board wiring. Obviously, this example is specific to the electronics area but points to a more general design requirement; the provision of tools to easily capture solutions to learning problems produced in the real world. Depending on the context, these might be implemented using cameras and/or microphones for video, photographic or audio capture.

In the near future, we plan to work with teachers to develop appropriate representations of logged data and a user interface specifically designed to support the needs of classroom teaching. We will also investigate alternatives to Moodle for implementing support for in class teaching as some of these (e.g. LAMS) may already support some of our requirements. We are also concerned to scale up from our initial studies, as we have so far worked with small groups of learners and only within the field of electronics. In the future we intend to work with some full school classes (30 learners) and in different domains, for example science teaching.

5. Acknowledgements

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