CASE STUDY

Student use of whiteboards in the classroom

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Abstract

This paper discusses the use of whiteboards – both small, individual boards and larger, wall-mounted ones – within a variety of classes within our undergraduate mathematics degree. Details of those classes, and how students use whiteboards within them are presented. There is a focus on practicalities, particularly regarding the formation of student groups for whiteboard activities and the role of the member of staff in such classes. Issues which should be considered if introducing these to the classroom are discussed.

Keywords: Boards, whiteboards, group-working, group facilitation, whiteboarding.

1. Background

It is not surprising that in a technological era there is a plethora of research on the advantages and use of interactive whiteboards, electronic voting systems and other advanced technologies for the classroom. For this case study we have taken a technological step back in order to discuss how students can use erasable boards within the classroom. We refer to 'whiteboards' because that is what we have, but chalkboards would be as effective for much of what is discussed here.

Students' use of whiteboards in both school and university has been reported in a number of studies. For example, Forrester, Sandison and Denny (2017) examine a case study following the experience of a teacher introducing the use of whiteboards into secondary school teaching of mathematics. The teacher reported that the use of whiteboards increased student engagement, confidence, discourse and collaboration. She was able to monitor students' mathematical thinking, intervene and encourage student abilities.

Antoniades (2013) credits Sean Kavanaugh as championing the use of whiteboards, in the junior classroom, by creating and implementing the 360 Degree Math System where "the teacher becomes the audience and the students become the performers".

Schaffner et al (2015) also found benefits of whiteboarding and reported on their use by high school students and concluded that they made student thinking visible, provided immediate and effective feedback, encouraged mathematical communication and resilience, and demanded more participation from students.

There is a lack of theoretical models to explain why the use of whiteboards may result in improved student learning. However, Carpenter's (2009) study suggests that getting students to access prior knowledge along with collaboration and discussion cultivates deeper understanding of complex subjects.

Seaton et al (2014) reported on the use, in three Australian universities, of 'whiteboarding' where students work collaboratively at a large board, with occasional tutor assistance. They identified numerous advantages to this: the process promoted more active learning; it improved the quality and timeliness of the help given by the tutor; it promoted peer learning; it improved connections between students and so helped retention; it improved relations between students and staff; it improved group work and communication; it provided students with a more authentic representation of the work of a research mathematician (particularly around collaboration and experimentation), and that it helped tutors to understand how students were progressing.

Inouye et al. (2017) used hand-held individual whiteboards within lectures in animal physiology classes, and occasionally required students to work in groups on the boards to answer questions. They found improved student performance in those topics where whiteboards were used. Megowan-Romanowicz (2016) describes whiteboard use in high school physics classes, and describes how whiteboards are an "important cognitive and communicative tool for both teacher and students". She discusses how students use the boards to discover ideas and negotiate with their peers, and says they "afford the teacher a valuable window on student thinking as it is happening."

This paper reports on students' use of whiteboards, but within that overarching idea there is a variety of different approaches used by different tutors, in different modules (five of which are included here), across all three levels of the undergraduate mathematics programme at our institution.

2. Modules

The modules covered by this paper are briefly described in Table 1. Four of the five modules take place in classrooms where the tables are arranged in groups of six-eight students, and a single two hour class combines elements of lecture and tutorial. The fifth has a more traditional 'lecture plus tutorials' format.

Table 1: Modules in which students use whiteboards.

Year	Module code	Core/ Elective	Number of students	Content	Delivery
1	1A	Core	~80-100	Revision and extension of A-level topics such as calculus, plus material new to most students such as complex numbers and Taylor series.	Parallel one-hour tutorial classes (~20 students per class) with one tutor and a two-hour lecture (full cohort) later in the day.
	1B	Core	~80-100	Topics such as set theory, proof, group theory, number bases, Euclidean algorithm. Most content new to most students.	Parallel two-hour workshop for half the cohort, with two tutors. A mixture of content delivery, interspersed with student exercises.
2	2C	Core	~80-100	Fourier analysis, analytical and (primarily) numerical solution or	As for Module 1B, but with an element of flipped learning; approximately half

				ordinary differential equations.	the material delivered via video lectures which students watch before the class
3	3D	Elective	~25	Partial differential equations: derivation from first principles, analytical and numerical solutions.	A single two hour session delivered by one tutor. The first hour is mainly delivery of new material, with the second hour for students to work on tutorial sheets.
	3E	Elective	~50	Group theory, formal languages and automata.	A single two hour workshop, delivered by two tutors; as with Modules 1B and 2C, a mixture of material delivery with student exercises. Students are asked to form support groups at the start of the year, and sit with the same group in each session.

3. Individual whiteboards

Initially, individual whiteboards were introduced in some classes as a simple, cheap, effective, low-tech means for a lecturer to pose questions and see student responses quickly (for example, asking students to sketch some graph, and then hold this up in the direction of the lecturer - Figure1). As with electronic voting systems, this is helpful for the lecturer to judge how well the class understand the material. However the whiteboards are more versatile as students can write mathematical objects and draw on the boards. Furthermore, the whiteboards are not subject to technological malfunction.

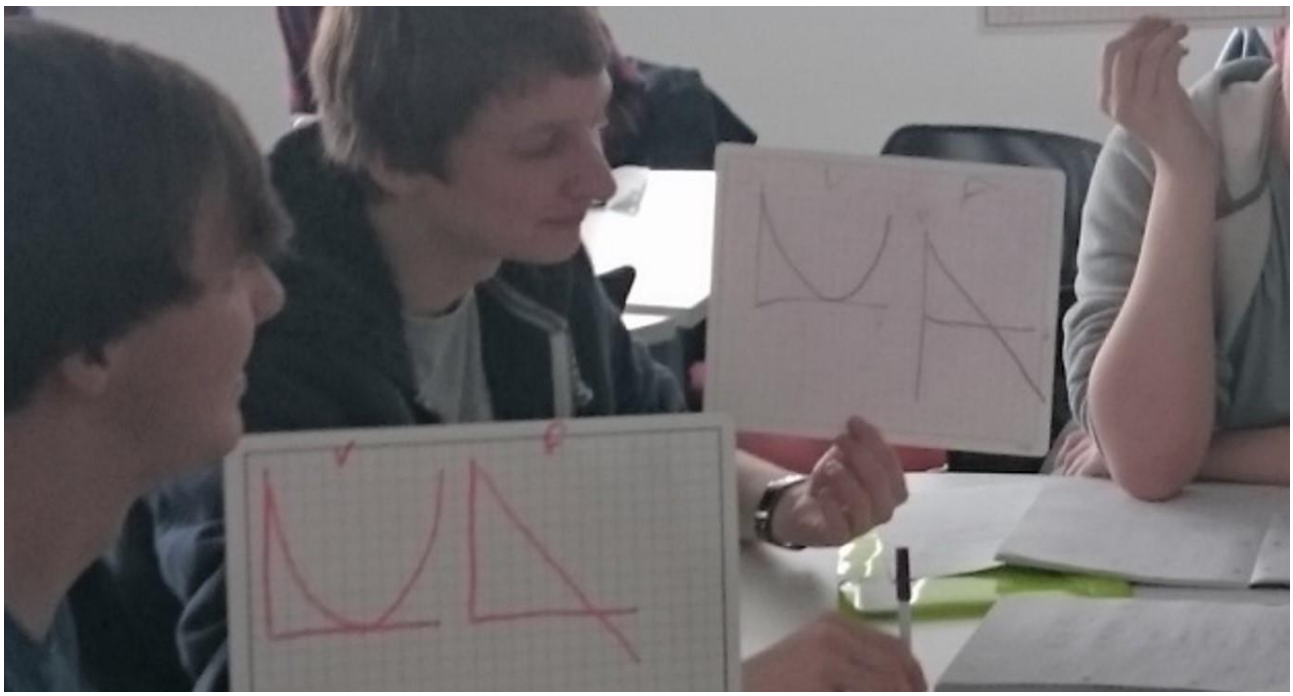

Figure 1: Students using individual whiteboards in response to a question posed by the lecturer.

It was observed that, once such individual boards were available, some students chose to use them in other ways, for example when working on set exercises or when sharing their ideas with other students.

As a result, in Modules 1B, 2C and 3E, the students are now given individual whiteboards in most teaching sessions, regardless of whether the lecturer *requires* their use. Their use is often recommended for exercises, especially when students are asked to try something before the correct answers are presented to the class. Many students opt to use the whiteboards available to work on exercises even without the recommendation. Some copy up the answer once it has been seen by a lecturer and some take a photograph of the work they produced.

4. Large whiteboards

Large, wall-mounted whiteboards are used in different ways in Modules 1A, 1B, 3D and 3E. The distinctions are discussed below, but generally, students are split into small groups (typically three-four students, but pairs and larger groups have been tried) and set exercises to complete collaboratively, whilst standing at a whiteboard. In some classes, every student in the group is given a whiteboard pen (in some cases, a different colour for each student) whereas in other cases, the group gets just one pen between them. The tutor moves between the various groups, observing, and intervening as they see fit. Students are encouraged to keep a record of the work by photographing it before erasing the board.

A key aim of introducing whiteboard work was to make students work together. It is worth noting that, in a more traditional exercise class, many students already choose to work in groups with their friends. There are advantages to students developing the skills to deal with having to work with unfamiliar peers. With this in mind, a variety of methods was used for forming groups:

- Students were asked to pair-up, and then the tutor joined together two pairs; thus students had one chosen peer, and two they had not chosen;
- Students were grouped according to some arbitrary factor, for example arranging themselves according to birthday, or last two digits of their phone number. This exercise works as an

icebreaker in Module 1A when the students have only just met each other; it also allows for students to ‘cheat’ if they really want to work with a friend;
- Students were allowed to self-select their groups completely;
- Students were formed into self-selecting study groups at the start of the year; when board work was used, they continue to work in the same study group. Thus the same group is very familiar with working together;
- Students were allocated groups by the tutor, with the aim of each group having a mix of personalities which would promote interaction;
- Students were asked to assess which exercises they needed to work on, and grouped with other students who wanted to work on the same questions.

Details concerning how whiteboards are used are given below:

4.1. Weekly board tutorials

In Module 1A, large boards were introduced in 2016/17 in most of the tutorial classes (21 out of 24 weeks), starting in the students' first week on the course. Students work at the board for most of the class; we therefore refer to this as a 'board tutorial'. The activity is introduced with care, with explanations about the purpose, discussions about working collaboratively and criticising constructively, and a recognition that this might be initially uncomfortable. These themes are reiterated regularly over the first few weeks.

The exercises set within Module 1A were modified, slightly, compared with the exercises from the previous year. In general, each set of exercises contained a combination of three elements:

- exercises based on the previous week’s lecture, enabling the tutors to check student understanding of previous material;
- exercises based on A level material which was to be revised and extended in the lecture later in the day;
- exercises designed to encourage students to ‘discover’ for themselves the results which would be formally taught later in the day.

The latter two elements in particular provided a means for the lecturer to modify the lecture plans, skimming over revision material which students clearly understood, going into more depth with material with which they struggled, and building on what students had 'discovered' when presenting the new material.

4.2. Occasional whiteboard use

The whiteboards are used infrequently in several modules, as discussed below.

In Module 1B, the students are *sometimes* (typically every three-four weeks) asked to use the large whiteboards instead of working at the tables. The exercise typically lasts around 10 minutes and then the students return to their tables to be taught or to continue with other exercises. The exercises are not re-written for whiteboard exercises, but the lecturers judge which questions would be suitable for such a task. They are used when group work and being able to easily erase written work would be beneficial.

In module 3E, there is just one board tutorial during the year, in addition to the usual two hour workshop. This takes place with about 25 students in the presence of two tutors. The students work on a question that involves proof by contradiction where they are given examples which are expected to lead to common mistakes. The large whiteboards are used for this session to encourage group

discussion about the errors and because the students would only have to erase part of the solution when trying a different approach.

In Modules 2C and 3D, large whiteboards are used within revision sessions, which happen in the final three weeks at the end of year. This method is preferred to a tutor-led approach in order for the students to construct their own understanding and for the tutor to provide help where it is most needed. The students are split into groups and asked to work on questions from past papers.

Figure 2: Students working at large whiteboards during a 'board tutorial'.

5. The role of staff within sessions

5.1. During the use of individual whiteboards

Whilst the students are working on exercises, staff move around, looking at work in the same way as work done on paper. A big difference is that staff also use the individual whiteboards to talk through solutions with individual students or to give them a hint to get started with an exercise. This is particularly useful when several students are working together. The whiteboard can be held up to show more than one student at once.

5.2. Large whiteboard sessions

The approach taken by all staff within the large whiteboards sessions is roughly the same across different modules. Whilst students try the exercises, staff move between the groups, eavesdropping on student conversations, observing their working on the boards, answering questions, and intervening when they deem it appropriate.

Staff, within any style of classroom, may answer questions, or otherwise intervene, in a wide variety of ways. Sometimes staff may choose a direct method: answering a question fully, demonstrating a method, or addressing a misconception. Often staff employ more indirect approaches, designed for example to foster students' development of independent thought and mathematical strategies. Board

tutorials, with their combination of group working, overheard conversations and easily visible mathematical working, facilitate effective tutor intervention in various ways.

Firstly, tutors can more easily assess students' comprehension of mathematical ideas and concepts, and their progress in applying these, which enables more effective and timely intervention. It is also possible to quickly see if students are disengaged from the work or failing to interact with other members of their group. Tutors can thus make more effective judgements about when and how to intervene whether in relation to mathematical ideas, engagement, or team working. This contrasts with a more traditional exercise class, where some students seek to hide their working (and with it, any problems), or avoid working at all, and this is less visible to the tutor.

Secondly, staff are able to visit each group of students frequently within a single session. This means that tutors are more able to, for example, provide a small hint, suggest that students think again about some part of their work, or solicit ideas from other members of the group and then, crucially, leave them to discuss this and work on the ideas, whilst being able to check on their progress either on the next visit to this group, or simply by glancing at their whiteboard. Within a more traditional exercise class, such approaches are restricted by the very limited opportunities for tutors to return to the same student 10 minutes later.

6. Conclusions

The student use of whiteboards has significantly changed the nature of some of our classes, to a degree which surprised the tutors, and made more modest changes in others. From a tutor's perspective, the most significant factors are:

1. Individual whiteboards are an effective way of questioning students during delivery of material; more flexible, cheaper, and simpler than electronic systems;
2. The use of whiteboards makes the student working - and so their thinking - much more visible to the tutors and other students. This is true to some extent with the individual whiteboards, but even more so with the use of large boards. As a result, the tutor interventions with students are more effective, and group working is facilitated;
3. In the board tutorials, it is much harder for students to be disengaged from the work; partly because their involvement with the rest of the group demands their attention, and partly because, whilst standing, any lack of engagement is more easily noted by the tutor.

We will be presenting a fuller evaluation of these ideas in an upcoming paper, including a detailed analysis of the students' perceptions of these approaches; however, for any staff considering using large whiteboards in their own classroom, we conclude with some issues for consideration:

- Classes need to be timetabled in suitable rooms with sufficient board space. This information is not always known to timetabling teams. Having a look around the university and providing the timetabling team with a list of suitable rooms makes it easier for all staff involved. If there are not any suitable rooms, you could request for additional whiteboards to be installed in some teaching rooms;
- Have a plan for how students with disabilities might be accommodated, particularly if this approach is to be used early in the course when students are not yet known to staff;
- Decide on the size of the groups and what might be appropriate for the activities which are planned. The experience of this work suggests three or four is ideal;
- Consider how the groups will be allocated. There is a tension between allowing students the comfort of working with their friends, and encouraging them to learn to work with others;
- Consider the nature of exercises to be set; some exercises may not be suitable and may need to be re-written for a whiteboard exercise.

7. Acknowledgements

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