Large lecture halls: Whiteboards, not bored students

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Biography:

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Introduction

Due to space, time, and budgetary constraints, many college mathematics faculty members teach in lecture halls filled with hundreds of students. These classes tend to be lecture-based [1], even though pure lecture increases failure rates in Science, Technology, Engineering, and Mathematics (STEM) courses by 55% as compared to techniques that actively involve students in the learning process [2]. Pure lecture contributes to calculus courses as barriers for prospective STEM students, lowering their confidence in themselves and their enjoyment with the discipline [3]. As such, these environments dissuade many capable students from pursuing STEM careers [4]. Accordingly, there is a need to adapt active learning methods to the context of large lecture halls (i.e. rooms with a large number of seats focused on a single presenter) [5]. Moreover, active learning helps reduce disparities between students from dominant groups and those historically marginalized in STEM classrooms [6–8] and the positive impact of active learning extends beyond the courses that initially featured active learning [9].

Innovative, learner-centered teaching methods have been applied in many college math settings [e.g., 10, 11]. Some methods have been adapted to large lecture halls, such as course response systems with peer instruction [12]. In this paper, I describe how personal whiteboards can be used as a low-cost method for increasing active engagement in lecture halls. I draw on personal reflections as an instructor and report from a brief student survey. The data come from a fall semester of introductory calculus in a classroom with 129 students from diverse backgrounds. As appropriate, I compare my experiences with personal whiteboards in calculus to my prior experiences in which I did not use them. The room I taught in had chairs bolted to tables, so students are not able to move around. Also, given the physical setup, the document camera was the only shared space that all students could see. Based on my experience, this physical setup of a lecture hall can make attending class sessions an isolating experience, which I believe the whiteboards can help counteract.

I begin this article with background on the use of personal whiteboards in K-12 settings. Then, the following sections discuss logistics, classroom norms, and instructional techniques associated with using personal whiteboards. This paper may serve as a reference for instructors who are already familiar with active learning and who wish to use it in a large lecture hall or for instructors who have experience teaching in large classrooms who would like to adopt more active learning methods.

Background: Use of Personal Whiteboards

Personal whiteboards have a long history in K-12 settings, particularly for use in formative assessment [13]. For instance, many of the formative assessment lessons developed by the expert lessons designers at the Shell Centre feature whiteboards [14] and the use of these lessons has a significant impact on student learning [15]. Like in peer instruction [12] and Peer-Assisted Reflection (PAR) [16, 17], whiteboards make it easy for students to write down an initial attempt to a problem and later revise their work. This can help normalize mistakes, which is important for STEM professionals who work in challenging environments where things rarely work the first time [18]. The use of whiteboards also challenges the idea that when it comes to mathematics, students either "get it" or they do not [19].

Personal whiteboards also support a collaborative learning environment. As a formative assessment tool, they make it easier for instructors to elicit and build on student thinking [13]. Similarly, they support group work by providing a shared workspace for students. These local peer interactions provide opportunities for students to speak more in class because the distribution of students who can speak in a whole-class discussion is limited by the large class size. Given the strong connections between talk and learning [20–22], this helps students learn more.

The Logistics of Using Personal Whiteboards

In this section, I review the setup required to teach effectively with whiteboards. Using individual whiteboards in a classroom of 100-400 students may seem daunting. However, personal experience shows it is feasible with nearly 150 students and these practices should scale beyond 200 or more students. Each student needs a: personal whiteboard, marker, and cloth eraser (e.g., socks are cheap and efficient).

The first step is to procure the boards. While many online vendors offer personal whiteboards, the most economical method is to purchase melamine panels, or "marker boards," from a local hardware store. Most stores will cut the panels to a desired size for a nominal cost. I purchased 32in by 4ft boards, which were cut into six 16in by 16in personal whiteboards. This size was ideal for a number of reasons: (1) it was small enough to fit in a student's workspace, (2) it provides sufficient space for solving relatively complex problems, and (3) when students need to share boards they can put two boards together for a larger workspace. A collection of over 100 boards is heavy; I taught in a separate building from my office so I used a utility cart to move the boards across campus (see Figure 1).

<INSERT FIGURE 1>

Once in the classroom, I placed the whiteboards at the front of the room. I arrived 5-10 minutes before class started so that students could pick up the boards as they entered the room. Students picked up their boards, erasers, and markers, and all students were seated with a board within 1-2 minutes of class starting. Similarly, students erased their boards and stacked them in the cart as they left, which occurred well within the 10-minute passing period before the next class.

Setting Norms

The introduction of whiteboards into a large lecture hall helps create an active space filled with mathematical discussions. With all of this activity and noise, it is critical to have an effective mechanism for getting students' attention. One technique is to use a digital timer with an alarm that can be projected in the front of the room. This gives students an explicit way to see how much time they have for an activity and to know when they need to come back for the plenary discussion. I also set the norm that when I raise my hand all students raise their hands and also quiet down. Sometimes I use a cowbell to help with this process; when I hit the cowbell, my students know to stop talking and raise their hands. Beyond particular techniques for getting student attention in a large classroom, setting norms in a large lecture hall is similar to setting norms in a smaller classroom setting. I now review some ideas around setting norms for instructors who may be new to active learning.

The use of whiteboards in the classroom helps students work together collaboratively and normalizes mistakes as a part of learning. To further support these goals, it is important to set norms that are consistent with this philosophy of teaching and learning. I recommend having a conversation with students to help develop such norms collaboratively, as this will allow students to feel more ownership over *their* classroom. Moreover, when students needed to be reminded of the norms I could remind them that these were *their* rules. In my class, I asked students what they thought needed to happen for the class to work effectively and then we had a class discussion. I began with two rules: be present, and be respectful. Those were my only contributions. My class generated the following list:

- Be present. Participate and ask questions.
- Be engaged and be engaging.
- Be respectful. Be positive.
- Be kind. Don’t make fun of others. Don’t be mean.
- Work together. Help each other.
- Speak up so everyone can hear you.
- Don’t distract others. Don’t pack up before class is over. No cellphones.
- Connect math to the real world. Solve things multiple ways.
- Have fun!

Norms such as “working together” and “solving things multiple ways” related specifically to the use of whiteboards for collaborative work, not just the whole class discussions. One way to help students make the distinction between these two aspects of classroom practice is to explicitly ask them to provide norms for both types of classroom interaction.

As described above, you may set explicit norms for group work. For reference, here are some norms that I have found effective in a variety of settings [23]. These norms help build resilience and normalize mistakes as a part of learning, which relate to my goals with using the whiteboards. Here they are:

1. Talk to your group members (not others).
2. Helping others does not mean giving answers.
3. Everyone stays together.
4. Ask, "why?"

5. Call the instructor for group questions only.

6. You have the responsibility to ask for help and the responsibility to offer it.

7. I can't...*yet!*

The norms of “talking to group members” and calling the instructor for “group questions” are valuable in a large lecture hall as there is only one instructor for many students, which makes it especially important for the students to build positive collaborative relationships with one another. While these norms can be useful as a reference point, one must also be careful about giving space for students to generate norms, which provides them with more ownership as compared to simply giving norms to students. To further normalize mistakes in learning, I provide the vocabulary reference in Table 1 [24].

<INSERT TABLE 1>

Instructional Techniques

In this section, I describe four common active learning techniques and how to use them with whiteboards in a large lecture hall. While some of these techniques may be used on their own, when combined with whiteboards it creates new potential for teaching and learning. The techniques are: warmups, student presentations, think-pair-share, and group work. A key goal of these techniques is to get students speaking more during class, which promotes better learning [20–22]. In particular, student-student talk is seen as “gold standard” [25, 26], which these techniques aim to promote.

Warmups

I begin each day with a warmup problem. The goal is to get students into “math mode” with a simple problem that all students should be able to make some progress on. I project the problems on the board before class starts so that students have something to think about as they get settled. I have found whiteboards to be extremely beneficial for improving student engagement with warmup problems. In past semesters without whiteboards, students seemed reticent to write anything because they did not want to use paper or mess up their notes. Instead, they waited to write the correct answers that were presented to the class. In my experience, whiteboards combat this problem, because students use the whiteboard for scratch work and write the correct answers on paper.

I often use conceptual true-false questions, which require students to explain their thinking and provide a counterexample as appropriate. In calculus, I have used statements such as: “the graph of a function can have at most two horizontal asymptotes,” or “if the derivative of a function is zero at a point, then it must have a local minimum or maximum at that point.” For these true-false questions, each student can write a T or F on their whiteboard, and hold it up to share their work. Students can also draw an appropriate graph or give an equation for a function as a counterexample, which is visible to their peers or in the front of the room.

Think-Pair-Share

Think-pair-share promotes talk between students. After posing a question: (1) have students think to themselves for 30-60 seconds, (2) talk to a peer for 30-60 seconds, and (3) then have a class discussion. Whiteboards enhance the process. During the “think” phase, students can jot down their thoughts and then actually show their work to their peers. Like with the warmups, this gives students a place for scratch work that they can easily erase.

Rather than putting students on the spot in a large lecture hall, think-pair-share gives them time to gather their thoughts before answering a question. The standard version of think-pair-share involves students sharing their own thoughts, but many variations are possible. Consider asking: (1) what is something interesting that your partner said? (2) who agreed with their partner from the start? or (3) who had different ideas from their partner? These questions make it easier for students to participate because they have the comfort of talking about what their partner said.

Group Work

I tend to have students work in pairs or groups of three; larger groups can be very challenging due to the physical arrangement of the room. Whiteboards facilitate collaborative work by creating a shared space for students to engage with mathematics (see Figure 2).

<INSERT FIGURE 2>

The primary challenge to facilitating group work is that the instructor is generally limited to interacting with the most accessible students (on the edges of rows) due to the physical setup. One way to address this is by mixing up the seating arrangements between classes. Even though it can be onerous, sometimes it can be helpful to walk to the inside of rows so that these students know that they are expected to participate even if they are in the middle of the room.

After students engage in group work, I find it helpful to have a synthesizing class discussion. The five practices for orchestrating mathematical discussions (anticipating, monitoring, selecting, sequencing, and connecting) provide tools for making such discussions work well [27]. In a ten-minute period, I am able to interact with a handful of groups, which gives me a sense of their thinking. This allows me to select and sequence student ideas in advance to “orchestrate” a discussion that I am confident will focus on big mathematical ideas. Moreover, this gives students advance warning that they will be asked to share, which lowers the barriers to sharing in such a large classroom.

Student Presentations

Whiteboards work well for student presentations, both in terms of logistics and for facilitating student interactions. Whiteboards help logistically, because it is easy for students to bring their boards to the front of the room and project them underneath the document camera. This allows them to share their work but saves time compared to having students rewrite all of their solutions. To organize these presentations, I often create sign-up slots where student groups volunteer to present. For instance, students may have 25 minutes to work on 5 problems. The students can work in any order, but as a community must present 5 solutions. During work time, I encourage groups to volunteer, provide reassurance regarding students’ solutions, and coach students on how to share. If extra whiteboards are available, students can place “completed” whiteboards at the front of the room and get new ones.

Whiteboards can help facilitate student-student interactions during these presentations, which promotes learning [25, 26]. An example of how whiteboards facilitated this talk arose spontaneously in my classroom. A student was in the front of the class presenting her sketch of a function based on its derivative. Another student in the class was trying to ask a question but was not able to communicate it effectively. In this situation, the student in the audience drew a function on her whiteboard, held it up, and asked her question. Even from the back of the room, the whiteboard was large enough that most of the class could see it and the presenter could respond to the question. Here the whiteboard supported other valuable types of communication beyond talk (e.g., inscription, gesture) [28]. In what follows, I now draw on data describing student experiences in this classroom.

Student Feedback

As with all new teaching methods, one may encounter some initial resistance from students. Nevertheless, student responses to the use of whiteboards and active learning in my class have been generally positive. During the fall 2016 semester I surveyed the 129 students in my course in the middle of the semester. Of the 109 who signed consent forms, 79 responded (a 72% response rate). The questions on the survey were general, and did not focus explicitly on whiteboards. Thus, while there are limitations to the claims that can be made about whiteboards, the surveys still provide insight into student experiences.

The survey questions were: (1) what is working well for you in this course that you would like to make sure I keep doing? (2) what can I do to better support you as a learner? and (3) what else should I know? While these were separate questions, in practice students provided responses to what was working well or not in any of the above three categories. Of the responses that students gave, the most frequent categories are given in Table 2. All other categories had three or fewer responses. Each category represents something that the students either highlighted as helpful or asked for more of in teaching. In other words, the table reflects what students valued in the learning environment. Students could provide multiple responses, so the responses do not sum to 79.

<INSERT TABLE 2>

In Table 2, the whiteboards category describes student responses focused specifically about the value of using whiteboards in class. In the peer interaction category, I included student responses that discussed working with peers without making specific reference to whiteboards. Thus, these categories were mutually exclusive, meaning that 40 of 79 students who responded (51%) stated that either peer collaboration was one of the best features of the course or that they requested more time spent on it. Students made statements such as:

- I'm a shy person and don't really talk to anyone in my class. Today we used wipe [sic] boards and I really liked that. It was fun, and for some reason was more helpful in understanding and doing the problems.
- The days in which we practice problems together on white boards are effective in reinforcing different concepts that we've previously learned.

Eleven percent of respondents said that they felt comfortable participating in this class. Because comfort level was not a survey question, it is possible that many more students felt similarly. They made comments such as:

- I really enjoy this class. [I appreciate your] walking around and asking individual people how they're doing. Your attitude makes me not afraid to ask questions.
- It's very nice how when students ask questions, you answer them politely and don't criticize. I like how I am not afraid to ask questions. The environment of this class is friendly.

While only a subset of the class made such statements, their description of calculus taught in a large lecture hall as supportive is encouraging. This contrasts national studies that show that introductory calculus tends to significantly decrease students' confidence, enjoyment with mathematics, and interest to continue in the discipline [3].

Although students were generally focused on the collaborative learning environment, there were 12 students (15%) who either stated that they felt direct instruction was the most helpful aspect of the learning environment or that they wanted to see more instructor-led examples. They made statements such as:

- More time explaining concepts and working through more difficult examples would help.
- I feel that we get into groups and things a little too much and it distracts from learning the material.

This is somewhat expected, as in many ways the classroom environment that students were presented with here differed from their expectations. This is especially true for students who may have previously taken a pure lecture version of college-level.

Other areas of focus for students were: (1) to have more detail worked out in examples, and (2) additional help on the Peer-Assisted Reflection (PAR) problems [17], which was a particular active learning technique used in the class. Some of the other things students noted as helpful were: the use of small section breakouts, having practice problems for the exams, and office hours. Because each of these categories only represented a few students, they were not included in Table 2.

Discussion

Large lecture halls are not ideal learning environments, but they can be active ones. This paper introduces a number of ideas for using personal whiteboards in large classrooms. Personal whiteboards are a low-tech solution for instructors who aim to improve student engagement and broaden the realm of teaching strategies available. The use of whiteboards can help set up a classroom environment that normalizes mistakes and communicates to students their instructor's interest in their learning.

The techniques offered in this paper relate to my own personal experiences and data collection was limited to a general course survey. As such, future work could include a survey that specifically asked students about their experiences with the whiteboards. Moreover, focus groups with students would provide deeper insights into what worked well and did not. If these results were contrasted with another calculus section that did not include whiteboards, it would help highlight the specifics affordances and limitation of the approach.

There are many ways that these ideas could be extended to improve student learning in a large lecture hall. For instance, whiteboards could be used in conjunction with course response systems (clickers), social media (to project student solutions during work time), or the "flipping" of the classroom. Given that many of us are unlikely to stop teaching in large lecture halls in the short term, there is plenty of room for exploring these ideas further.

References

1. Apkarian, N., Kirin, D. 2016: Active learning in undergraduate precalculus and single variable calculus. In: Fukawa-Connelly, T., Infante, N., Wawro, M., and Brown, S. (eds.) Proceedings of the 19th Annual Conference on Research in Undergraduate Mathematics Education. pp. 512–514, Pittsburgh, PA
2. Freeman, S., Eddy, S.L., McDonough, M., Smith, M.K., Okoroafor, N., Jordt, H., Wenderoth, M.P. 2014: Active learning increases student performance in science, engineering, and mathematics. Proceedings of the National Academy of Sciences. 201319030. doi:10.1073/pnas.1319030111
3. Bressoud, D.M., Carlson, M.P., Mesa, V., Rasmussen, C. 2013: The calculus student: Insights from the Mathematical Association of America national study. *International Journal of Mathematics Education Science and Technology*. 44, 685–698. doi:10.1080/0020739X.2013.798874
4. Seymour, E., Hewitt, N.M. 1997: Talking about leaving: Why undergraduates leave the sciences. Westview Press, Boulder, CO

5. Marotta, S.M., Hargis, J. 2011: Low-threshold active teaching methods for mathematic instruction. *PRIMUS*. 21, 377–392. doi:10.1080/10511971003754135
6. Fullilove, R.E., Treisman, P.U. 1990: Mathematics achievement among African American undergraduates at the University of California, Berkeley: An evaluation of the mathematics workshop program. *Journal of Negro Education*. 59, 463–478
7. Laursen, S.L., Hassi, M.L., Kogan, M., Weston, T.J. 2014: Benefits for women and men of inquiry-based learning in college mathematics: A multi-institution study. *Journal of Research in Mathematics Education*. 45, 406–418
8. President's Council of Advisors on Science and Technology. 2012: Engage to excel: Producing one million additional college graduates with degrees in science, technology, engineering, and mathematics. Executive Office of the President, Washington, D.C.
9. Kogan, M., Laursen, S.L. 2014: Assessing long-term effects of inquiry-based learning: A case study from college mathematics. *Innovative Higher Education*. 39, 183–199. doi:10.1007/s10755-013-9269-9
10. Alsardary, S., Blumberg, P. 2009: Interactive, learner-centered methods of teaching mathematics. *PRIMUS*. 19, 401–416. doi:10.1080/10511970701678596
11. Wawro, M., Rasmussen, C., Zandieh, M., Sweeney, G.F., Larson, C. 2012: An inquiry-oriented approach to span and linear independence: The case of the magic carpet ride sequence. *PRIMUS*. 22, 577–599. doi:10.1080/10511970.2012.667516
12. Crouch, C.H., Mazur, E. 2001: Peer instruction: Ten years of experience and results. *American Journal of Physics*. 69, 970–977. doi:10.1119/1.1374249
13. Black, P., Harrison, C., Lee, C. 2003: Assessment for learning: Putting it into practice. Open University Press, Berkshire, England
14. Mathematics Assessment Project. 2017: Index of classroom challenges, http://map.mathshell.org/lessons.php
15. Herman, J., Epstein, S., Leon, S., Matrundola, D.L.T., Reber, S., Choi, K. 2014: Implementation and effects of LDC and MDC in Kentucky districts. University of California, National Center for Research on Evaluation, Standards, and Student Testing (CRESST), Los Angeles
16. Reinholz, D.L. 2015: The assessment cycle: A model for learning through peer assessment. *Assessment and Evaluation in Higher Education*. 1–15. doi:10.1080/02602938.2015.1008982
17. Reinholz, D.L. 2015: Peer-Assisted Reflection: A design-based intervention for improving success in calculus. *International Journal of Research in Undergraduate Mathematics Education*. 1, 234–267. doi:10.1007/s40753-015-0005-y
18. Dounas-Frazer, D.R., Lewandowski, H.J. 2016: Nothing works the first time: An expert experimental physics epistemology. Presented at the Annual Physics Education Research Conference.
19. Schoenfeld, A.H. 1998: When good teaching leads to bad results: The disasters of "well-taught" mathematics courses. *Educational Psychologist*. 23, 145–166
20. Bransford, J., Brown, A.L., Cocking, R.R. 2000: How people learn: Brain, mind, experience, and school. National Academies Press, Washington, DC
21. Lampert, M. 1990: When the problem Is not the question and the solution is not the answer: Mathematical knowing and teaching. *American Educational Research Journal*. 27, 29–63
22. Sfard, A. 2008: Thinking as communicating: Human development, the growth of discourses, and mathematizing. Cambridge University Press, New York, NY

23. Featherstone, H., Crespo, S., Jilk, L.M., Oslund, J.A., Parks, A.N., Wood, M.B. 2011: Smarter together! Collaboration and equity in the elementary math classroom. National Council of Teachers of Mathematics, Reston, VA
24. Mindful Schools. 2015: Resilient habits of mind, https://www.facebook.com/mindfulschools/photos/a.203073253066340.49931.165948186778847/1023252594381731/?type=3&theater
25. Hufferd-Ackles, K., Fuson, K.C., Sherin, M.G. 2004: Describing levels and components of a math-talk learning community. *Journal of Research in Mathematics Education*. 81–116
26. Michaels, S., O'Connor, M.C., Hall, M.W., Resnick, L.B. 2010: Accountable Talk® sourcebook. Institute for Learning, Pittsburgh, PA
27. Smith, M., Stein, M. 2011: 5 practices for orchestrating productive mathematics discussions. National Council of Teachers of Mathematics. National Council of Teachers of Mathematics, Reston, VA
28. Abrahamson, D. 2009: Embodied design: Constructing means for constructing meaning. *Educational Studies in Mathematics*. 70, 27–47

Table 1. Vocabulary for building resilience in the classroom.

Instead of	Try thinking
• I'm not good at this	• What am I missing?
• I give up.	• I'll use some of the strategies I've learned.
• This is too hard.	• This may take some time and effort.
• I can't make this any better.	• I can always improve, so I'll keep trying.
• I just can't do math.	• I'm going to train my brain.
• I made a mistake.	• Mistakes help me learn.
• She's so smart. I will never be that smart.	• Let me figure out how she does it so I can try it.
• It's good enough.	• Is this really my best work?
• Plan A didn't work.	• Good thing the alphabet has 25 more letters

Table 2. Student response to the mid-semester survey

Category	Example	Number of Students
Whiteboards	"Have more whiteboard parties."	19
Peer Interactions	"[Include] more interactive methods of learning!"	21
Friendly/supportive environment	"I like how I am not afraid to ask questions."	9
Direct Instruction	"More teacher working on problems, less students going up."	12
Slower Pace / More Detail	"Go slightly slower when going through problems on the projector."	21
Help on PAR problems	"Make PARs a little easier."	14

Figure 1. Utility cart of whiteboards.

Figure 2. Students working collaboratively with whiteboards.