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In Process: 20160429

Patron:
Reference #: 10077162

Journal Title: Einstein Fellows : best practices in STEM education /

Volume:
Issue:
Month/Year: 2014
Pages: 275-299

Article Author: Buffy Cushman-Patz

Article Title: Using whiteboards to create a student-centered, collaborative classroom

Imprint: New York : Peter Lang, [2014]

Notes: Borrowing Notes: SHARES Member; **Please scan image pages in color or grayscale**

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Chapter 12

USING WHITEBOARDS TO CREATE A STUDENT-CENTERED, COLLABORATIVE CLASSROOM

Buffy Cushman-Patz

Introduction

A Whiteboarding Classroom

It is 12:50. The bell for C-block is still ringing as the last students walk through the door. They rush to the board at the front of the room to see which problems are left or what their partners have chosen. They then quickly head to their tables, drop their backpacks, and check in with their group-mates: "What are we working on?" "Which one did you pick?" or "How did you get that?" they ask. They grab markers, quickly pull out their homework, and jump into further conversation with their partners.

It is algebra class, and these students are whiteboarding.

Within the next 10 minutes, they will work in their groups of two or three to present their solution to one of last night's homework problems. Meanwhile, I will walk around the room, looking quietly over each group member's shoulders to check his or her homework for completion. Sometimes the group members stop me to ask a quick clarifying question; sometimes they are too engrossed in their work to notice me. (I leave the answer key open at the front of the room so they can check for themselves the "Is this the right answer?" queries. The answers are not what whiteboarding is about. The *process* is, so letting them have access to them does not spoil anything.)

They take their roles seriously. They know that by choosing the problem they have chosen, they are taking responsibility for helping their classmates solve this problem and others like it. They know that if there is widespread confusion, I will step in to help, but otherwise the task is up to them. They know their classmates will have real, probing questions for them, so it is in everyone's best interest for them to be clear and thorough in their explanations, including organizing their work neatly on the whiteboard.

After I have made the rounds, I call out, "Finish up your whiteboards in one minute." As they complete their whiteboards, they bring the boards to the back of the room and set them down, move to their tables, and pull out the supplies we have agreed they need for whiteboarding presentation sessions: completed homework, colored pen for editing, and their original source material (e.g., textbook, worksheet) from which they are all working, open to the relevant page.

By the time I reach my seat at the back of the room, the first group is usually up at the front of the room with their whiteboards set in the tray of the wall-mounted chalkboard, and the three presenters are standing next to it, waiting for the silent cue from me. The presenters read the original question and then explain to their classmates how they solved it and what their group consensus was about the answer. The audience members compare their own homework to the solutions presented and ask the presenters questions about differences they see. My role is to sit, watch, and listen. This is their process, for their learning, and I try to be just a "fly on the wall."

Once the group has finished its presentation and the other class members have had a chance to compare their work and ask questions, the audience applauds the presenters, and the next group heads up to the front to repeat the process.

Whiteboarding as a Practice

I was originally exposed to the concept of whiteboarding at a Modeling Physics workshop I attended at Arizona State University in Tempe. As in all the best professional development, we learned by doing. We spent the 3-week workshop learning the content in the same way we would later help our students learn it, so that we could experience it through the eyes of a learner. During that workshop I was able to feel what it was like to be a student in a whiteboarding classroom, thanks to an expert teacher-facilitator committed to developing us as a community of learners. I felt the way that whiteboarding (as

well as the modeling approach) democratized the classroom and empowered me as a learner—even in a room full of people who, I was sure, knew more about the content than I did.

I came back from that summer's modeling workshop so committed to creating a whiteboarding culture in my classroom that I decided to try to implement it in all of my classes at the time: seventh-grade Math and Chemistry (in addition to Physics). Later, when I began teaching Algebra, I incorporated it from Day One. I also spread the gospel to my colleagues in other disciplines—English and history included—and within a year 2–3 whiteboards could be found in several classrooms throughout the school. The practice of whiteboarding changed my classroom, changed my relationship with my students, and enabled student learning and depth of understanding at a level I did not know was possible until I experienced it myself.

This chapter documents what I learned along the way and the system I developed through years of refinement, so that you can implement it in your classrooms, too.

Background

Decades of education research have spoken volumes about how people learn. Our role as educators is to create learning environments for our students that take into account what we know about the conditions that enhance and enable learning. A successful whiteboarding classroom puts into practice many of the principles we know are true about student learning.

Designing the Learning Environment

First and foremost, in a whiteboarding classroom, students have the opportunity to talk about the content they are learning and teach each other. They have the chance to collaborate with other students, test out their ideas, and then present them to an authentic audience. Teachers, in turn, have the opportunity to use these formative assessments to learn what their students have learned and, if necessary, adjust instruction. Whiteboarding plays a critical role in the series of steps necessary for students to retain information and to truly learn it.

Learning Through Application and Repetition. "The more elaborately we encode information at the moment of learning, the stronger the memory," reports Medina (2008). The practice of whiteboarding can play an important

role in creating meaningful and contextual experiences in the early stages of the learning process.

Wiggins and McTighe, the authors of *Understanding by Design*, describe the cyclical nature of well-designed learning experiences: "part to whole, whole to part—that is how we come to understand and use our knowledge" (2005, p. 251). They describe the cycle as one familiar to any coach or performer—the movement back and forth, from content to performance and back again, from discrete skill to strategy and back again (Wiggins & McTighe, 2005). Whiteboarding as a classroom practice plays a critical role in this cycle by providing students an opportunity to "perform" skills. Repeated whiteboarding sessions within a unit of content allow students to encode information in meaningful ways consistent with using this cycle.

Students Talking. In *Ready, Set, Science!* the authors describe the importance of student talk:

> In order to process, make sense of, and learn from their ideas, observations, and experiences, students must talk about them. Talk, in general, is an important and integral part of learning, and students should have regular opportunities to talk through their ideas, collectively, in all subject areas. Talk forces students to think about and articulate their ideas. Talk can also provide an impetus for students to reflect on what they do—and do not—understand. (Michaels, Shouse, & Schweingruber, 2008, p. 88)

Whiteboarding provides multiple opportunities for talking, first in small groups as students prepare their whiteboards, and then as a larger class community during whiteboarding presentations.

Students Teaching Each Other. A decade's worth of data about peer instruction (PI) shows the positive impact of students learning from and teaching each other. Peer instruction, as described by Crouch and Mazur (2001), who implemented PI in physics courses at Harvard University, is a process of peer teaching that "engages students during class through activities that require each student to apply the core concepts being presented, and then to explain those concepts to their fellow students" (p. 970). They found that through peer instruction "students' grasp of the course material improves according to a number of different measures...both during class, and when tested for retention at the end of the semester" (p. 970).

Whiteboarding provides opportunities for students to collaborate and teach each other—not once, but twice within a class session. Students peer-teach

during the stage of the whiteboarding process when they create their whiteboards; they then re-teach the material, even if they have only just learned it from a peer, during the presentation of the whiteboards to the whole class.

Learning in a Safe Classroom Climate. In *How People Learn*, the authors describe the attributes of learning environments that must be cultivated, noting that "learning is influenced in fundamental ways by the context in which it takes place" (Bransford, Brown, & Cocking, 2000, p. 25).

> The norms established in the classroom have strong effects on students' achievement. In some schools, the norms could be expressed as "don't get caught not knowing something." Others encourage academic risk-taking and opportunities to make mistakes, obtain feedback, and revise. Clearly, if students are able to reveal their preconceptions about a subject matter, their questions, and their progress towards understanding, the norms of the school must support their doing so.
>
> Teachers must attend to designing classroom activities and helping students organize their work in ways that promote the kind of intellectual camaraderie and the attitudes towards learning that build a sense of community. In such a community, students might help one another solve problems by building on each other's knowledge, asking questions to clarify explanations, and suggesting avenues that would move the group towards its goals. (Bransford, Brown, & Cocking, 2000, p. 25)

Formative Assessment to Inform Instruction. The *Understanding by Design* process emphasizes the regular use of formal and informal assessment, noting the ability of formative assessment or "assessment-in-progress" to "ferret out the apparent from the genuine understandings" (Wiggins & McTighe, 2005, p. 247).

Teachers in a whiteboarding classroom are able to use whiteboarding sessions as formative assessment tools to learn what their students have learned and to adjust instruction.

Meeting Next Generation Standards

Common Core State Standards (CCSS), *Next Generation Science Standards* (NGSS), and 21st Century Skills Standards all recognize that student learning is not only about content, but also about students' ability to deeply understand content, transfer it into new settings, and communicate it to others. These new standards are based on much of the same research referenced here. Whiteboarding is a strategy that can help implement some of these best practices while

helping students become proficient at the performance expectations associated with new standards.

The *Common Core State Standards for Mathematical Practice* describe "varieties of expertise that mathematics educators at all levels should seek to develop in their students. These practices rest on important 'processes and proficiencies' with longstanding importance in mathematics education." These include:

1. Make sense of problems and persevere in solving them.
2. Reason abstractly and quantitatively.
3. Construct viable arguments and critique the reasoning of others.
4. Model with mathematics.
5. Use appropriate tools strategically.
6. Attend to precision.
7. Look for and make use of structure.
8. Look for and express regularity in repeated reasoning. (*Common core state standards*, 2010)

Whiteboarding, as a classroom practice, overtly provides students with opportunities to construct viable arguments and critique others' reasoning. Further, it creates rich opportunities to attend to virtually *all* of the other mathematical practices, especially with well-thought-out questioning practices from the audience of the students' peers and teacher.

The eight practices of science and engineering, identified by the *Framework for K–12 Science Education* (National Research Council, 2012) and incorporated into the NGSS, are similar in scope to the CCSS Math Standards. The practices of science and engineering are:

1. Asking questions (for science) and defining problems (for engineering)
2. Developing and using models
3. Planning and carrying out investigations
4. Analyzing and interpreting data
5. Using mathematics and computational thinking
6. Constructing explanations (for science) and designing solutions (for engineering)

7. Engaging in argument from evidence
8. Obtaining, evaluating, and communicating information. (National Research Council, 2012)

Again, whiteboarding provides rich opportunities for practices 6, 7, and 8, and has the potential to play a role in the other practices, as well.

Best Practices: How to Adapt Whiteboarding to Your Classroom

The goal of whiteboarding is to enable students to take ownership of their own work and also to play a role in helping their fellow students learn. This requires an intellectually safe classroom culture where collaboration is valued over competition, and where the success of individuals depends on the success of the group, and vice versa. For many students (and many teachers!), this is a shift that takes time to develop. Effective and efficient whiteboarding in a smoothly running classroom, like the one I described in the introduction, requires clear roles and expectations for students (and teachers), introduced early and referred to often.

What I describe below are the details of the practices I developed over a 5-year period as I implemented whiteboarding in my mathematics classes with an 80-minute block schedule. Even though I use—and love—whiteboarding in other classes, I wrote this chapter looking through my lens as a mathematics teacher, because the transformation in my teaching practice and in the classroom environment was significant as a result of whiteboarding.

Whiteboarding can be used in any classroom, in any discipline; the processes and practices described can be modified as needed. Specific suggestions for modifications are included in the next section of this chapter.

[Note. Throughout the rest of this chapter I will use the word "whiteboard" as both a noun and a verb. *Whiteboard* (*noun*): A two-foot by three-foot (by 1/8-inch) sheet of melamine or similar substance with a surface that can be marked on with dry-erase markers or crayons. *Whiteboard* (*verb*): The process of writing or drawing on whiteboards, and/or presenting the written-on whiteboards.]

Building the Culture

In a smoothly running whiteboarding classroom, after the systems have been developed and the collaborative culture has been fortified, the students, in

essence, run the class by themselves. The teacher's role becomes the "guide on the side" in a dynamic learning community.

It is important to establish norms and guidelines for the various steps of the process: creating the whiteboards, presenting the whiteboards, and being an audience member for whiteboarding presentations. Each of these steps will take practice, and it is important to evaluate the class's success as you go along and, if necessary, modify the guidelines appropriately or discuss specific strategies to adhere to the expectations.

Embedded in the following sections are sample sets of guidelines about the different steps of whiteboarding that my students and I developed over time. I share these with new groups of students at the beginning of a course, and they provide a clear set of expectations for how we will develop a whiteboarding culture. At first, students (and teachers) will need regular reminders to stay within the established guidelines; over time, the guidelines will develop into standards of practice for the classroom as a community of learners. Persistence is key. Consistency is essential. It will take patience—with your students and with yourself—as you collectively develop the habits of a whiteboarding classroom.

Creating Productive Student Groups

Developing student groupings before class increases the efficiency of the whiteboarding experience. The number of groups ideally ranges from four to seven, with two to four students per group, but depending upon class size, teachers may need to create more or larger groups. For the sake of time and audience patience, it is best to have no more than six whiteboard presentations per class period; the exact number your class can tolerate will depend on your students and the length of your classes.

Whiteboarding provides excellent opportunities to create mixed groups so that there are both teaching and learning opportunities within each group. I make sure that each group has a student who has demonstrated mastery of related topics and who will likely be able to successfully teach some of his/her peers, and that each group includes a student who is challenged by the topics and may benefit from working with peers with a more thorough understanding of the ideas. The whiteboard creation phase provides excellent opportunities for student-to-student teaching in small groups. Students are especially good at explaining concepts using language that is accessible to their fellow students.

Regular rotation of students within groupings allows them to work with a variety of their classmates over time. It also provides relief for less successful

groupings. I prefer to rotate student groups weekly. Students know when they walk in on Monday that they will be getting new group-mates, and they look first thing to the board to find out who their group-mates are. Classroom seating arrangements are not permanently fixed; groups sit together within the classroom for ease of collaboration.

Selecting Problems for Students to Whiteboard

What students whiteboard about is actually the least important part of the whole whiteboarding process and is entirely dependent on the subject material and instructional goals. One method of selecting whiteboarding topics is described here; another is described at the end of this chapter in the "Modifications" section. There are infinitely more variations, which I encourage you and your students to explore. In my mathematics class, I had students whiteboard homework or classwork questions, and I describe how to replicate that process here.

Allow students to whiteboard questions or problems they have already had time to think about individually or in groups, either as homework or as classwork. To facilitate students getting to work as soon as they enter the classroom, write the problem numbers on the board before class begins and let the student groups select problems they want to whiteboard as soon as they enter the classroom.

One significant consideration in selecting problems is to aim for each student group to work for relatively equal amounts of time to prepare their boards. Depending on the problem sets, this may manifest in any of a number of ways:

- If all problems are fairly similar, each group can prepare a whiteboard about one problem.
- If there are multiple problems that are solved similarly, some groups may be responsible for all (or some) similar problems.
- If there is a particularly long investigation, multiple groups may present different parts of the investigation (e.g., Group 1 works on #5a while Group 2 presents #5b and #5c), ideally after checking with each other.
- If the homework or classwork set included more problems than there are groups to prepare and present (e.g., the homework had 10 problems but there are only 6 groups), include the problems that are most critical for students to understand or review. As an alternative, list more prob-

lems than there are groups to solve them. Then you can either encourage student groups who finish their preparations early to take on additional problems, or create whiteboards yourself for those problems. (As long as this is reserved for rare occasions, it can be fun for the teacher to pop into the lineup of presentations right along with the students.)

In light of all these options, it is critical to know the mathematical challenges that may crop up so that you can anticipate relative lengths of time it will take groups to prepare and present the problems.

Choosing Their Own Problems

Teachers who thoughtfully select a variety of problems from which students can choose empower students to then choose those problems that they feel most comfortable explaining and presenting.

Whenever possible, I let student groups choose without any interference. However, there are times when I circumvent this. If there is a particularly challenging problem, and a group who I think would be best suited to handle it, I let them know I think they are up for a challenge and ask if they will take on the tough one. Sometimes this gets negotiated with a promise of extra help from me during preparation, but this works out just fine in the end. Even if I help them through a problem they were completely stuck on themselves, *they* are the ones who end up teaching it to the rest of their classmates. This way they learn the concept even better during the process of teaching it, even if they had not worked it out on their own to start with.

If there are more groups than problems, allow more than one group to sign up for the more challenging questions/problems, so that you can either have both groups present and compare solution methodology, or draw straws right before presentations to choose which group will present (being sure the group that does not present today gets a chance to present tomorrow).

Preparing Whiteboards

Once class begins, student groups have approximately 10 minutes to prepare their whiteboards for presentations. The details on how their group wants to approach the preparation are up to them. Every group has a slightly different approach. Only in extreme situations do I intervene; it is important that students take ownership of their learning and understanding during this phase. The parameters are clear: they have a limited amount of time, and they have

resources available to them (their completed homework, their textbooks, their notes, and their group mates). They have a clear "product" that they are working to produce: a presentation to their peers that will enable them to understand the problem.

Some groups have a clear leader who delegates roles to the group members. Many groups pull out their homework and compare answers first, check disparate answers with the answer key available to them, then decide how they want to prepare their board. Some groups begin writing immediately, then discuss, using their board for visual cues. All of these are effective approaches, and it is revealing to watch students as they learn to work with new (as well as familiar) partners and better develop a sense of their own learning needs and approaches. As the year goes on, students become more willing to assert their own needs and desires for effective learning. If necessary, I coach students on effective collaboration strategies and language.

Guidelines for Whiteboard Creation

- Think about what information is essential and what is not. Include only essential information!
- Show all relevant and non-trivial steps of your work.
- Use board space efficiently and organize your work logically.
- Write neatly, clearly, and large enough so that someone in the back of the room can see your board.
- Include appropriate figures and drawings relevant to the problem.
- Use color effectively: write words in easy-to-read colors. Consider color-coding your work to distinguish different parts.
- All group members are responsible for understanding every part of what is on your whiteboard, and any of you may be asked questions about the material, so make sure you understand and approve of everything on your board before you present.

Sidenote: Checking Homework. In this 10-minute period during which students are working together to prepare whiteboards, I circulate the room to check students' homework for completion. Students reference their homework

as they are preparing their whiteboards, so it is already lying on the table or desk. A quick glance for completion and effort takes only a few seconds; it is possible to record each student's completion rating (e.g., on a clipboard) and move on to the next group, often without disturbing the students' collaborative work session. Circulating while students are working also allows for listening to students' work processes, as well as making you available in case students have pressing questions they can't work out within their groups.

Preparing for Presentations

Getting students to stop preparing their whiteboards and transition to becoming audience members for presentations can be challenging, especially when student groups are productively engaged in the work. It is helpful to give warnings (e.g., 2 minutes left; 1 minute left) before asking students to stop preparing their boards. Using an automated timer, especially one that students can see as they work, may also be helpful.

When whiteboard preparation time is over, use a set of procedures to signal this shift. Students must put markers down, move their marker bins back to their storage place in the room, and move their completed whiteboards to the designated place in the room (ideally the back of the room, where they remain out of sight until they are presented). Students then move to their seats and pull out the supplies they need for actively listening to and engaging with the presenters: their completed homework, the source material for the questions/problems so that they can reference what the question asked and what information was given, and a pen to make notes or corrections to their homework as they learn from the presentations. (I require students to use a color pen so that these changes can be clearly distinguished—by them, most importantly, but also by me—from their original work.)

Presentations begin once the audience is seated and prepared. The teacher, acting as an audience member along with the students, takes a seat near the back or side of the classroom. Transitioning from preparing whiteboards to preparing for presentations should use no more than 2 minutes of precious class time, so students need plenty of warning and clear systems to guide them.

Giving Presentations

Presenting groups stand at the front of the room with their whiteboards (ideally set on an easel or in the tray of a wall-mounted board) and describe the question

or problem they are presenting and the method and thought process they used to approach it. Presenting students should reference their boards as they speak, but speak directly to their audience (their peers, not the teacher), making eye contact and using good presentation skills such as appropriate volume, posture, and so on. All presenters in a group should have a role in the presentation. Initial descriptions of the boards and the process they used to solve the problem should take no more than 2 minutes. The remaining time is used for questions and answers.

Guidelines for Whiteboard Presentations

- Explain how you thought about the problem and why you decided to solve it the way you did. (This is the most important part of your presentation!)
- Briefly explain the process and/or steps you used. Explain any possible variations that other students may have (or that you found within your group).
- Expect questions. Be willing to listen carefully to other ideas or methods for solving the problem, and compare them to your own.
- If, while presenting, you determine that revisions or corrections are in order, note them by drawing a line through the original work and writing new/revised information above or beside it (ideally with a different-color pen). Mistakes are instructive; please leave them on the board! Also, it may confuse your audience if the answer changes, and they happened to be looking at their own papers while you made the change.
- Stand up straight, speak loudly and clearly, and be succinct.
- Be sure that all group members have a significant role in the presentation.
- Be conscious of where you are standing—make sure all your classmates have a clear view of the board.

Asking Questions

The audience members' objective during presentations is to understand the presenters' method of solving the problem at hand in relation to their own method for solving it. In some cases it will be the same; in many cases it will be different. The primary role of audience members during presentations is to ask questions that elucidate the various ways to approach a problem, and for the class to come to a consensus about the correct answer(s) to the problem at hand, despite the various approaches for finding it. The secondary role of audience members is to check their own homework answers against this group consensus once it is achieved, and to notate their work accordingly.

Developing students' questioning skills is a key component of the presentation stage of the whiteboarding process. The intent of this whiteboarding process is to create a culture of collaboration, with students learning from each other rather than competing against each other.

A basic rule for audience members during presentations is that they only ask questions; they may not make declarative statements. For some students (and teachers!), it is a challenge (a necessary one) just to turn statements into questions. For example, instead of saying "That is not what the question asked for," a student might ask, "Are you sure that is what the question was asking for?" A next-level challenge, once students have made a habit of asking questions, is to make sure those questions are open-ended, with no implication of right or wrong. One example of this would be when a student might ask, "Can you clarify what the question was asking for?" Another example of a progression, as a student develops his/her technique, might be, "You did not do the second step correctly," to "Are you sure your second step is right?" to "Can you explain again how you did the second step?"

When students are able to consistently engage in non-judgmental questioning of one another, they are able to drop their defenses and open their minds to new ideas and new ways of doing things. They begin to stop worrying so much about who is right and focus more on understanding and helping each other understand.

Guidelines for Whiteboard Audience

- You are responsible for checking the work on the board and comparing it to your own finished work. If your work disagrees with the presenters' work, ask questions of the presenters to understand

their reasoning and methods. (There is no guarantee that the presenters' answers are right, so it is to everyone's benefit for you to ask them clarifying questions!)

- You may only ask questions; you may not make declarative statements.

Instead of:	*Ask:*
You didn't put a unit on your answer.	What are the units for your answer?
You got 15. I got 8. Is my answer okay?	Can you explain how you got 15?
You wrote the question wrong.	Can you clarify the question asked?

- You are responsible for making any necessary revisions/additions to your own work/homework in colored pen.
- Applaud (clap for) all presentations once everyone has had a chance to check the work and ask questions.
- You may not make changes to your own whiteboards once presentations have started.

Guiding Q&A Sessions

The role of the teacher during presentations is to listen as much as possible and to intervene as little as possible. The presenters, and not the teacher, should call on audience members who have questions. The students should self-correct their questioning approaches (to the extent possible) if they slip into making statements. Students are responsible for paying attention to the presenters during their presentations, as well as other questioners, such that if an audience member asks a question that has already been answered while (s)he was not paying attention, the other students (rather than the teacher) will point that out to him or her. Again, the overarching goal is to give the *students* the primary responsibility for their learning experience.

In some circumstances it is necessary for the teacher to intervene. If the discussion has become overly circular or chaotic, and the presentation is confusing

a majority of audience members rather than helping them, the teacher should intervene with a directed question that clarifies. If the presenters have given an incorrect solution or methodology, and the audience's questions have not helped the presenters to successfully revise their boards, then the teacher must ask a question that draws attention to the source of the error. At any point that the teacher needs to intervene, (s)he should use questioning techniques consistent with the expectations for student questioning.

The teacher may also need to guide the conversation in one of several ways. If only one presenter is responding to audience questions, the teacher may follow up the next question by asking a particular presenter to respond. If students are mispronouncing content vocabulary, the teacher may need to provide the correct pronunciation. (Usually this is necessary only once or twice before students take on the role of helping each other to correctly pronounce words.) If an audience member is not adhering to the guidelines set forth, or is distracting classmates or the presenters, the teacher may need to address an audience member directly. Teachers should limit themselves to one intervention per presentation.

Finally, the teacher serves as the ultimate timekeeper. Although (s)he may delegate the formal timekeeping role to a student helper, the teacher may need to extend a presentation's Q&A segment when it is especially beneficial to all students, or may need to speed up a presentation when time is running short. The teacher has the overarching pacing goals in mind, and (s)he must budget the precious class time accordingly.

Finishing Presentations

After each presentation, the designated timekeeper or teacher cues the audience by saying, "Let's thank the presenters." Audience members applaud in recognition of presenters' energy and efforts. Presenters return their whiteboards to the back of the room and set them down in their designated spot. Whiteboards can be returned without being erased. This is both for efficiency and for reference in case any further questions come up during the class period about the solutions presented. Presenters then sit down with their classmates and become audience members for the next groups.

Assessing

The purpose of whiteboarding is, of course, learning: learning content, learning to collaborate, learning to explain one's thinking, and learning to understand others' thinking. In a successful whiteboarding session, the teacher is able to hear all students in the class use content-specific language in context and get a sense of their thinking processes. This is formative assessment at its purest, as it in*forms* the teacher about student learning and gives him or her plenty of in*form*ation about where students—individually or collectively—are having difficulty or are showing improvement or understanding.

Grading the whiteboarding process itself may be counterproductive to its goals. We want to encourage *learning*, not a grade, as the primary motivation for whiteboarding. Teachers and students both learn during productive whiteboarding sessions, and this learning can be transferred to other potential assessment situations. I prefer to use whiteboarding as a primarily informative assessment situation and let students experience the learning potential in the low-stakes, collaborative culture that the whiteboarding classroom creates.

If it is necessary to "grade" students during whiteboarding, here are a few ideas for how to do so while still remaining consistent with whiteboarding's philosophy.

1. Develop a rubric, consistent with the guidelines that you lay out, by which students may self-assess their presentations. Alternately, let peers assess each other's presentations using the rubric, and/or based on their understanding of the concepts after the presentation.

2. At the end of the week during which they worked together, develop a rubric by which students may assess each other's collaborative work skills and contributions to the group.

3. Allow students to improve their homework scores by turning in corrections or clarifications they made to their own work (clearly noted in colored pen as different from their original work!) by listening to the presentations.

4. Allow students who attempted all problems and showed all work (as confirmed by the teacher while students were preparing their whiteboards at the beginning of the class session) to earn a homework score of "exceeds proficiency" if the student determined, by listening to the presentations, that (s)he answered all homework questions correctly.

Improving the Culture

The first segment of the Best Practice section was titled "Building the Culture," and this final segment is about culture as well. An intellectually safe, collaborative culture is the foundation of any successful whiteboarding classroom, and creating one is an iterative, ongoing process. It will take constant work—and constant learning and improvement along the way.

As you are transitioning to a student-centered classroom from a teacher-centered one, hold yourself and your students to the guidelines laid out throughout this chapter, even if it feels hard or unnatural at first. Be consistent with your students and yourself. Pay heed to the pitfalls described below. You will find that you will change as a result of developing these practices into a habit. And your students will change. So will your relationship with your students and their relationship with the content.

Whiteboarding works when the students feel safe and comfortable enough to share their ideas and their thought processes with their classmates and with the teacher. This safety develops from being asked (and asking) open-ended, non-judgmental questions. It develops when negative language ("No, that's not right" and "Don't do it that way") is replaced by positive suggestions ("Let's see how you got that" and "Let's try this a different way"). And it develops from being a part of a learning community where students know that it is not only okay to be wrong, but that significant learning can come from mistakes.

How will you know if your learning community is succeeding? How will you know how your students feel about the whiteboarding culture? Ask them! After a few weeks (or months) of implementing whiteboarding, spend 10 minutes at the end of a class instituting a "Plus/Delta" session, in which you encourage students to give (out loud, in written form, or digitally) feedback in the form of Plusses—things that are working well and that they like—and Deltas—things that they would like to see improved upon or changed, and suggestions for how. Plus/Deltas are an excellent opportunity to give students an even greater voice in the classroom community, but it is essential that the teacher be willing to respond to the Deltas and implement changes and to take ownership of his or her own role in shaping the culture.

Modifications

What I described above are the step-by-step details of how I used whiteboarding to transform my mathematics classes from dull, practice-and-repeat, teacher-

centered lessons (even I was bored!) to student-centered, *fun*, investigative approaches to learning and teaching mathematics. But whiteboarding can also be used in a variety of science, technology, engineering, and math (STEM) classes, and in more ways than have been described so far.

Two other particularly effective ways to use whiteboarding are Board Meetings and Gallery Walks.

Board Meetings. A variation on one-group-at-a-time whiteboarding presentations is the "board meeting" or "meeting in the round" concept. In this instance, all groups stand in a circle and present their findings or solutions, usually to the same problem or challenge, at the same time. This allows students to compare notes with each other and discuss similarities and differences in their data, their responses, and their approaches to solving and/or presenting. Board meetings are an especially good way to build consensus and to develop the concept of a community of learners. In chemistry class, we used board meetings for students to compare how they classified a variety of substances as Matter or Not Matter, and then used the collective responses as fodder for discussion about the properties of matter, allowing students to develop their own working definition of matter. In physics class, we used board meetings to compare data collected from experiments—for example, position versus time data for a cart on a ramp—and students were able to compare the shapes of their graphs even if they had not used the same slope or time intervals for their data collection.

Gallery Walks. Gallery walks can be used in a variety of ways, but are particularly useful when students are examining similar or related content. In this case, student groups prepare whiteboards, then place them in a part of the room where they can be easily accessed by groups of people standing nearby. All groups set up their whiteboards simultaneously in different parts of the room, and class members circulate ("walk") the room ("gallery") examining the various boards. Depending on the task, one group member may stay stationed at the group's board to explain the board to viewers.

Gallery walks are useful after students have brainstormed on a topic in small groups. Groups can then circulate to learn what other groups brainstormed and to push their own thinking on a topic. Gallery walks can also be a useful extension of the jigsaw cooperative learning technique, in which a large chunk of material is subdivided and each group takes ownership of sharing a section of the material with classmates. Whiteboards can facilitate presentations of what individuals or groups learned, and that they now need to share with their peers.

Pitfalls to Avoid

Developing a smoothly functioning whiteboarding classroom takes time, and the process continuously evolves as the students and teachers do. The practices I describe here are those that I developed over years of working with students and developing my whiteboarding classroom. The more I work with students, the more I learn and the more ideas I have for improvement. The same will be true in any classroom.

There are many potential stumbling blocks in the process of developing a highly functioning whiteboarding classroom. Here are some of the ones I have encountered or have seen other whiteboarding teachers encounter, along with my suggestions for avoiding or adjusting them.

Students Splitting the Work Without Collaborating. Like all of us, students look for shortcuts and time savers when possible. For some student groups, this amounts to splitting the work of preparing a whiteboard into sections, and each student taking responsibility for a part of it. If the students within a group do not collaborate on their parts, this can lead to presenters making statements like "I don't know, that wasn't my part," or discovering when their whiteboard is being presented that they disagree with the work that one of their classmates has done.

One way to avoid the "divide and conquer" mentality among students is to allow only one dry-erase marker per group. This encourages student groups to discuss their ideas collectively before deciding what will be written on the whiteboard. Once students have established this as a practice, which may take a few weeks or months, it may then be possible to allow more markers per group for efficiency, to encourage students to discuss before writing.

Another way to ensure that students take collective responsibility for the work on their whiteboards is to make sure that all presenting students respond to questions from the audience. Ideally, the presenting students learn to self-regulate this process and take turns responding to questions. However, if one or more presenting students dominates the questioning session, then the teacher may need to gently redirect audience questions to the silent group member(s). As a general practice, each presenting student should make at least one substantial contribution to each presentation. Even group members who were previously absent can contribute by reading/describing the problem at hand. Having been absent does *not* disqualify students from being able to contribute to their group during discussions or presentations!

Reverting to a Teacher-Centered Classroom. There are two common traps that ensnare teachers who are still transitioning from a teacher-centered classroom to a student-centered one: invading students' whiteboard space, and allowing students to direct presentations to the teacher rather than to their fellow students.

Invading Students' Whiteboard Space. The goal of whiteboarding is to give *students* ownership of their work, their knowledge, and their understanding. To fully give them this control, teachers must treat the whiteboards almost as a part of their bodies. (We would not straighten a student's shirt for them or fix their belt—we would, instead, tell them about a problem we notice and have them fix it themselves.) We should do the same for whiteboards and consider the board as students' property. The most disempowering thing a teacher can do is walk up to a whiteboard that students are presenting and mark on it or take control of the conversation by taking over their physical space.

A teacher should intervene on a whiteboard presentation only if all student questioning has been exhausted or the presenters have become confused themselves to the point of being entirely unhelpful to the class's understanding of a concept. In such a case the teacher should *ask* the presenters if he or she may come up and help. Likely they will say yes, at which point the teacher can then invite the students back to their seats and lead a brief clarifying discussion. If at all possible, this discussion should use a different chalkboard or whiteboard, enabling the students' whiteboard to remain intact as a point of reference for the teacher-led conversation.

Students Presenting to the Teacher Rather Than Their Classmates. During presentations, presenters should speak to the audience of their peers, not the teacher. Students should make eye contact and interact with their fellow peers during presentations. If necessary, remind students who their audience is. I have often told my students that I already know the content; it is their peers with whom they are in the learning process. It is critical, of course, that you actually mean what you say and let the students genuinely *be* the audience, not you.

Being Taken by Surprise by the Answers (and Processes) Students Present. Not every whiteboard presentation that makes it to the front of the room needs to have perfectly correct answers on it; a lot of learning can come from discussion of incorrect answers. However, it is to your benefit, as the facilitator, and to your students' benefit, as learners, if you have a sense ahead of time of which presentations *must* have more prolific discussions in order to ensure that all students understand the processes.

While students are preparing their whiteboards, use the time to walk around the room and get a sense of the board contents. In some cases it is helpful to talk a group through their challenge and let them correct their board before they formally present to the rest of the class. In other cases, it is useful to clarify with them verbally, but ask them to leave the mistake on the board so that the audience finds the error and asks questions about it. This ensures a fruitful, efficient, student-centered discussion during the presentation. In some cases, it is instructive to let whiteboards be presented with mistakes or errors on them without letting students know that you have noticed them. I would allow errors to be deliberately presented only when the group members were strong, confident students who I knew could handle an on-the-fly reaction to being challenged by their classmates.

Knowing your students' strengths, weaknesses, and sensitivities comes into play in this decision-making process. In groups with a highly sensitive or shy student—especially during the early weeks of whiteboarding, while you are still building the class culture—I prefer to (at least) alert them of (and usually allow them to edit) something that other students may challenge or have questions about, so that they are not caught completely off-guard in front of the audience. In cases of confident students, or students that fellow class members tend to revere as "always right," I am more apt to let them present with a mistake on their board. The culture of the classroom can benefit from strategically allowing "wrong answers" to make it to the front of the room.

Spending Too Much (or Not Enough) Time Whiteboarding. Time is the most precious commodity we have in schools and in our classrooms, and how we spend our time should reflect what we value most. Whiteboarding, an opportunity for students to be collaboratively engaged in talking and thinking about content, is a highly valuable activity and deserves a large chunk of class time, even if that means re-organizing other activities that we had formerly spent class time on. That said, it is important to develop systems and routines that encourage students to be efficient.

Whiteboarding works very well with block schedules. Working with an 80-minute block, our time breakdown (for math class) looked like this:

- 10 minutes—creating whiteboards, teacher checking homework;
- 35 minutes—whiteboard presentations, Q&A, and transitions;
- 35 minutes—teacher-led discussion of new concepts, students practicing those concepts;

- 0 minutes—students choosing problems or writing down homework questions for that night. The problems are posted on the board as students enter the classroom, and can be selected even before the bell rings. Homework is posted on a small section of the board at the front of the room and remains there until the next day; homework is also posted online.

Additional Pitfalls. In order to be completely honest about pitfalls, I must admit that there are several challenges that I am still working on and still figuring out the best way to handle. Some of the struggles that continue to challenge me include the following.

Ensuring Students Make the Most of Their Group Time. While I think it is important that students have autonomy in determining how their group interacts during the collaboration/preparation phase, I need to do a better job of introducing them to strategies, practices, protocols, and language that would enhance their ability to interact with their peers in constructive ways.

Enabling Students to Focus on Understanding the Process. Since most students have grown up in a school system in which getting the "right" answer is the end goal, it is hard (and understandably so) to break them of the habit of trying to make sure they have the right answer above all else. Throughout the year, as our classroom becomes more and more of a whiteboarding classroom, the students begin to value more and more the processes and understanding they are experiencing. However, I have noticed that this seems to translate more to how they give presentations and less to how well they listen to them. There is room for improvement in students' listening for understanding during whiteboarding presentations. I am still trying to figure out the best way to dis-incentivize the focus on the "right answer" above all else.

Managing Time Wisely. Ah, time. We never have enough of it, do we? It is a constant struggle to allow the necessary discussions and interactions that whiteboarding brings to a classroom *and* to introduce students to new concepts in the investigative and student-centered way I want to, all in the same block of time. I admit that the 80-minute block schedule I sketched out earlier in this chapter is my ideal; we do not always stick to that schedule as well as I would like to, and we end up needing to make adjustments to fit everything in. I am not sure this will ever get resolved, but it is a good problem to have when students have so much to say about their thinking that I do not want to stop them.

Conclusion

Students love whiteboarding. On days when our schedule was shortened, or when we needed to adjust our schedule to review for an assessment (or take one), students would walk into the classroom and see that there were no problems posted on the board and say with sadness and some indignation, "What? No whiteboarding today?" If two or more days passed without whiteboarding, they would whine, "When are we going to whiteboard again?" Students often remarked, as the bell rang at the end of an *80-minute math block*, "Really? Class is over? Time always passes so quickly in here!"

What is it they love so much? I daresay they love learning. They love being in control of their own learning. They love working with their peers and having a sense of control over how they spend their time. They love being able to stand up while they make their whiteboards if they want to, and move around the room a bit when it is their turn to present. They also love drawing with markers!

In our whiteboarding classroom, we were able to create an environment in which learning was fun, even though the work was challenging. As educators, we all know this is possible. We love learning. I share this best practice with you in the hope that it will help you create an environment in which students become as passionate about learning as you are about teaching.

As you implement whiteboarding and internalize these practices, *they* will change *you*. And the culture of your classroom will change as a result.

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Appendix: Recommended Supplies

Item	Details	Quantity	Notes
Whiteboards	2'x3' pieces cut from ⅛" melamine	10–15	• Ideal number of whiteboards is at least twice as many as the number of groups in your largest class. • Large ⅛" melamine sheets are available at Home Depot for under $20; ask them to cut them into six 2'x3' sheets for you.
Markers	Four-color packs are useful	1 set of 4 colors per group	• It is useful to store the markers in small plastic bins, in sets of four with erasers.
Erasers		1 per group	• Store in bins with markers.
Whiteboard cleaner solution		1 bottle	• Cleaning whiteboards a few times a month is a good task for student helpers, and it helps maintain the boards' lifespans.