Turning Teaching Upside Down

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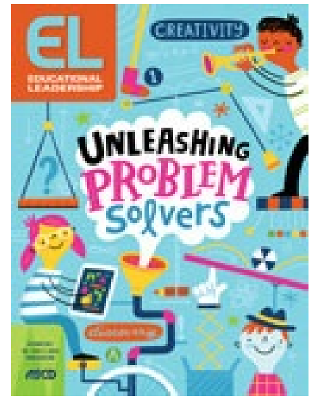

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Students learn more when we let them wrestle with a math problem before we teach them how to solve it.

Back in the 20th century, I was taught how to teach mathematics pretty much the same way I had learned it. My fellow preservice teachers and I were told to prepare our lessons thoroughly, present the intended concept or procedure clearly (and with enthusiasm!), and guide students as they worked through some examples. Eventually, we would assign homework, including a few word problems in which students would apply the procedure they had just learned. We hoped students would ask questions if they didn't understand.

The way I learned to teach mathematics was not that different from the way teachers learned to teach other subjects. But in the years since then, we've begun to realize that this one-way delivery of information may set students up for frustration and failure, especially when they're faced with challenging problems they haven't been taught how to solve. If we teach students solely by providing them with specific procedures to solve predictable problems, how will they learn to deal with problems that don't look like those at the end of the chapter?

An alternative model that I call *upside-down teaching* can better prepare students to be strong, flexible problem solvers. In this model (see fig. 1), teachers don't wait to assign a problem until they've taught students how to solve it. Instead, upside-down teaching starts with a problem or task that students may not already know how to solve (Seeley, 2014; 2016).

Figure 1. Traditional Teaching vs. Upside-Down Teaching

Traditional Teaching	Upside-Down Teaching
1. *I* explain the procedure or concept.	1. *You* tackle a problem you may not know how to solve yet.
2. *We* work examples together.	2. *We* talk together about your thinking and your work.
3. *You* apply what you just learned to solve a word problem.	3. *I* help connect the class discussion to the goal of the lesson.

Struggling on Purpose

In the past, many of us tried to protect our students from failure, especially in math class. As a result, generations of students have learned to give up whenever a problem gets hard. But it turns out that constructively struggling with mathematical ideas can engage students' thinking and help them learn to persevere in problem solving (National Council of Teachers of Mathematics, 2014). Emerging from the *growth mindset* research of Carol Dweck (2007), we now know that an individual's brain grows when he or she struggles in a productive way with something difficult—like a challenging math problem (Boaler, 2015).

More and more teachers are confirming that students can benefit from wrestling with problems they haven't specifically been taught how to solve. In the process, students learn about the power of effort and persistence, become more confident problem solvers, and even grow their intelligence.

Upside-Down Teaching in Action

Unlike the traditional teacher-centered classroom based on lecture, an upside-down classroom is teacher-structured, but centered on students' thinking. The goal of the lesson isn't simply for students to get the answer to a problem, but rather for students to learn the intended mathematics of the lesson using the problem as the basis for thinking and discussion. After selecting a problem to start the lesson, the teacher's job becomes orchestrating the discourse of the classroom—how students will share their thinking in ways that lead to the mathematical outcome of the lesson—and helping students connect the discussion to the mathematical goal. As the teacher circulates through the classroom, she generally asks questions to help students clarify their thinking or take it to the next level. While doing so, the teacher is also making decisions in the moment about which students will share their work with the whole class and in what order they will be called on.

Sometimes students' discussion will lead directly to the mathematical connection the teacher wants to make—as in a 2nd grade lesson involving subtraction that I'll describe further along in this article. Other times, the teacher may need to guide the conversation more directly toward the math outcome. In either case, students will have been engaged in thinking about the problem and, consequently, they're much more likely to learn the mathematics than if they were simply told what to do.

Let's consider four classroom examples that illustrate the upside-down concept and demonstrate the variety of tasks teachers might select to start an upside-down lesson.

Starting with an Engaging Photo or Video: How Many Cookies?

In a 2nd grade classroom, students watch a video of a furry hand reaching up behind a kitchen counter and taking away an unopened package of cookies. After some noisy chewing and rattling, the hand puts the package back on the counter with some cookies gone. The teacher then asks, "What did you notice in that video? What did you wonder?" The students talk about their observations and the teacher helps them focus on the question they finally agree to tackle: How many cookies did the cookie monster eat?

Students then work in pairs to solve the problem. As the teacher circulates among the pairs, she notices that students have approached the problem in different ways. One of the teacher's key roles in this kind of teaching is deciding who she will call on during the whole-class discussion and in what sequence students should present their work in order to highlight the different approaches. By the lesson's end, the teacher can write on the board a clear mathematical summary of students' work, helping students see that a subtraction equation might result from either a *take-away* situation or a *difference* situation and helping them notice that the two resulting equations are related.

This lesson setup is based on the Three-Act Lesson model created by Dan Meyer (2011). View an edited video of this lesson at Teaching Channel.

Starting with Real-Life Examples: What Happens with Bigger Tires?

Some problems might present everyday applications that are likely to engage students' interest. For example, in the excerpt of a 12th grade quantitative reasoning lesson shown in this video clip[1] The teacher brings in a tire (the spare from her car). She sets it on the floor and asks students to take note of the numbers on the tire and discuss what those numbers represent in terms of the tire's measurements. She then asks her students to consider what would happen if someone were to replace their vehicle's tires with bigger tires.

The class offers ideas, speculating that the tire size would affect how fast they could drive, their gas mileage, the accuracy of the odometer, whether the vehicle would take up more space on the road or in a parking spot, and so on. Eventually the teacher narrows down the discussion for students and the class decides to investigate of the effect on gas mileage if the tire size changes. She chooses this question so that students will be able to deepen their understanding of proportionality as they learn to use mathematical modeling in ill-defined problems. She then moves among the groups as they work on the problem in much the same fashion as the 2nd grade teacher in the "How Many Cookies" example, and the class culminates with students presenting their findings to the whole group.

Starting with a Basic Word Problem: How to Make Perfect Purple Paint?

A 6th grade teacher introduces the concept of ratios by presenting a fairly straightforward word problem. She shows students that she can achieve the perfect shade of purple paint by mixing 2 cups of blue paint with 3 cups of red paint. She then asks students to figure out, and to model with colored cubes and drawings, how many cups of red paint and blue paint would be needed to make 20 cups of perfect purple paint.

As students work in small groups to come up with pictures and models, the teacher moves through the classroom, seeing how they are progressing and asking questions to push their thinking. When a group comes up with three different solutions, the teacher reminds them that they will need to reach a group consensus. Instead of guiding students to the correct answer, she tells them she will return in a few minutes to see what they've agreed on. In this way, students gain experience in explaining their own ideas and listening to others' ideas. You can see an edited video of part of this lesson (from Illustrative Mathematics, the Smarter Balanced Assessment Consortium and Teaching Channel).

Starting with a Mistake: Are the Coordinates Correct?

A pre-calculus teacher puts a graph on the board with some coordinates labeled in two different colors. The teacher tells students there might be an error in the coordinates shown in red. Students work in pairs to discuss the posted work, considering whether there is a mistake and determining how they will make their case to the rest of the class. The teacher then convenes the class for a large-group discussion in which the students present their thinking to their peers, eventually coming to agreement about the correct solution. (You can see an edited video of this lesson from PBS Learning Media.)

What We Can Learn from These Upside-Down Classrooms

Short edited video excerpts of classrooms like these may not show all the elements of an upside-down lesson. In some of the full lessons for which excerpts are shown in the video clips above, for example, we can assume that the teacher helped students crystallize the mathematical conclusion at the end of the lesson (off screen). What we can notice across these examples, however, are the types of tasks the teachers have chosen and the ways the teachers orchestrate the classroom discourse.

In each of these classrooms, the teacher sets the stage with the whole group, elaborating the task or facilitating students in formulating the question they will try to answer. All four types of tasks used in these examples can readily be adapted to any grade level, and there are likely other types of problems or tasks that would also work well for upside-down lessons. In choosing tasks for such lessons, teachers look for "low-floor high-ceiling" tasks. This means looking for tasks with multiple entry points—so that essentially all students can access the task at some level—but that also allow for considerable depth or extension (Smith & Stein, 2011).

In terms of orchestrating discourse, the teachers in these classrooms move among students as they work, asking questions or offering comments like, "I notice that in your group you have three different models. I'll be back in a few minutes to see if you have agreed on which model you want to present to the class," or "Can you draw on your paper a picture of what you just said?" or "How did you decide to divide by 7?" When the teacher brings students together after their group work, students present their findings and solutions to the whole class, with the teacher asking clarifying questions, facilitating further discussion, and, finally, making explicit the mathematical connection between students' work and the mathematical goal of the lesson.

We also notice that sometimes students in these classrooms share answers or approaches that are incorrect. Teachers have learned that valuable classroom discussions can arise from wrong answers. Jo Boaler (2015) suggests that we actually learn more from making a mistake than from getting a right answer. Upside-down teaching helps both students and teachers understand that mistakes will happen, and that when they do, the class will use the opportunity to dig into the thinking that led to the mistake, leading to deeper understanding of the mathematics and increasing the likelihood that students will be able to use what they've learned to solve other problems in the future.

Teachers today have access to a growing body of publicly available classroom videos showing this kind of mathematics teaching, whether labeled *upside-down, problem-centered, student-focused*, or just math class. Videos such as those described here provide a great opportunity for individual reflection or professional discussion among colleagues. In looking at classrooms in real time or analyzing online videos, educators can ask questions like,

- ▪ What kind of problem or task does the teacher use to start the lesson?
- ▪ How does the teacher encourage students' thinking and stimulate student discourse?
- ▪ What kinds of questions does the teacher ask?
- ▪ What do you notice about the roles of the teacher and student?
- ▪ How does the teacher sequence students' presentation of their work?
- ▪ How does the teacher connect the class discussion to the mathematical outcome of the lesson?
- ▪ How is this classroom similar to or different from your classroom or the other classrooms you see?

Not all upside-down classrooms will complete a lesson in one class period or follow the same format. Effective upside-down classrooms differ noticeably in terms of how they're organized and how they flow. What they have in common is the focus on students engaging in thinking about a problem they haven't already been taught how to solve. The teacher sets the stage with the whole class, sometimes (but not always) facilitating discussion among students as they narrow down what they will explore in the lesson. Students then work on the task, individually or in groups, followed a whole-group discussion.

As we analyze such classrooms, we notice that they are heavily teacher-structured, but not teacher-centered. The focus is on students coming up with ideas, solutions, approaches, and models, even as the teacher facilitates the discussion and makes explicit the mathematical concepts revealed by students' work.

Making the Classroom a Safe Place to Share

When we look into classrooms that use an upside-down approach to problem solving, it becomes obvious that the students seem quite willing to share their thoughts and ideas. Regardless of their grade level, they don't seem to be anxious about the possibility of making a mistake or having an incorrect idea. They've come to expect that open discussion is what happens in math class.

This willingness to risk sharing their ideas doesn't come easily to students, and it doesn't happen overnight, especially for older students who over the years may have developed a reluctance to speak up in math class. The teachers in these examples have spent deliberate time making their classrooms conducive to respectful, open conversation. They have worked with students to create positive class norms that encourage every student to participate—norms based on respect and recognition of the value of everyone's ideas (Boaler, 2015; Chapin, O'Connor, & Anderson, 2013; Kazemi & Hintz, 2014). A culture in which all students appreciate the contributions of every other student not only promotes problem solving, but also makes a strong statement that equity is valued in our classrooms.

Upside-Down Teaching Every Day?

It may or may not make sense to use this kind of upside-down, problem-centered, student-focused approach every day. The main idea is to prioritize student thinking, reasoning, and problem solving every day and to structure classrooms where those outcomes are consistently valued. Some teachers will use an upside-down approach every day. Others may choose to include an occasional teacher-led lecture or presentation of an interesting mathematical idea or observation. Whatever way a teacher structures lessons, students should come to expect that when they walk in the door to math class, they're going to have lots of opportunities to talk about their thinking and share their reasoning as they take on challenging, interesting problems.

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Endnote

> [1] *This lesson and video comes from Advanced Quantitative Reasoning, a course developed by the Texas Association of Supervisors of Mathematics working with the Charles A. Dana Center at the University of Texas, Austin.*

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