FOSTERING STUDENT ENGAGEMENT WITH THE

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HEMERA TECHNOLOGIES/THINKSTOCK

Reflections on the design and implementation of the flipped instruction model in two mathematics classrooms.

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Amanda J. Moore,
Matthew R. Gillett, and
Michael D. Steele

The Common Core Standards for Mathematical Practice (CCSSI 2010) and NCTM's *Focus in High School Mathematics: Reasoning and Sense Making* (2009) present a vision of high school classrooms in which the majority of the activity involves students working on rich mathematical problems and engaging in mathematical discourse. This model stands in sharp contrast to lectures, demonstrations, and independent practice that have dominated classrooms in the United States (Stigler and Hiebert 1999). In the quest to spend more class time doing meaningful mathematics, teachers have increasingly turned to technology to support student learning. One recent model is the flipped classroom. We describe the history of the flipped classroom and report the results of experiments with variations on the flipped model with our own secondary school mathematics students.

The concept of the flipped classroom originated at the college level in the early 1990s through an effort led by Harvard University physics professor Erik Mazur (Mazur 2005). Early iterations included text files, interactive demonstrations, and problem solutions that allowed students to choose content that met their individual needs and addressed common misconceptions (Mazur 1991, p. 38). As technology progressed, the model evolved in colleges, including online and video resources such as eTEACH (Foertsch et al. 2002). Bergmann and Sams, high school chemistry teachers, adapted the model for secondary school classrooms to accommodate absent students and found that the video lessons could serve as a primary instructional resource, freeing up class time for more meaningful work on content (2012).

Descriptive and experimental research suggests that a flipped model affords more classroom time to engage with students and more opportunities for innovation and collaboration in class (Strayer 2007; Tucker 2012). Bergmann and Sams (2012) also noted that students were more engaged, came to class with stronger background knowledge, and thus were able to do more in class.

No canonical model exists for the flipped classroom; the research describes implementations that vary according to video source and length, differentiation strategies, the nature of in-class activities, and assessment strategies. As we conceptualized two flipped-classroom experiments, we investigated the ways in which two designs supported wider access to and participation by all students and instructional differentiation. In both designs, elements of direct instruction that used to occur during class would be accessed using online video at home in advance of class. Class time would be used for students to work collaboratively and discuss rich problems, thus strengthening conceptual understanding (Tucker 2012). We measured our success by homework completion, student engagement, and written student feedback.

As teachers interested in innovation, we found little specific information on critical features for implementing the flipped classroom and even less research investigating whether the model actually afforded more class time to engage with students and do rich mathematical tasks. Implementing *high cognitive demand tasks*, defined as procedures with connections to meaning or doing mathematics (Stein et al. 2009), correlates with increased student achievement and richer classroom discourse. As more resources are available to teachers and students to produce and use online video, flipped classroom models might better prepare students to engage with high cognitive demand tasks and thus change mathematics teaching and learning.

Co-authors Moore and Gillett, under the guidance of co-author Steele, created flipped classroom models and collected data on each. Both implementations collected baseline data on homework completion with standard problem sets before the flipped unit as a measure of student engagement. During the flipped units, we measured student engagement with the out-of-class videos using written assignments designed to show whether students had watched the videos and engaged with the key content. We measured changes in students' engagement and attitudes during class time, now spent collaboratively on mathematical tasks that had previously been done as homework. We selected homework videos from a variety of sources, including Khan Academy (Khan Academy® 2013), Brightstorm® (Brightstorm 2013; Brightstorm is a paid service, but the video content is a free resource), and teacher-created videos. **Table 1** shows the design choices that we made related to unit content, video sources and delivery, homework, and supports for students without home Internet access.

Table 1 Features of the Flipped Classroom Implementations

Design Element	Gillett	Moore
Video delivery	Weebly® with embedded videos	Edmodo® portal
Video source	• Brightstorm (early) • Teacher-created on YouTube (late)	VoiceThread®
Topics taught	• Surface area and volume for 3D shapes (early) • Similarity and right triangles (late)	Scaling perimeter and area, scale factors, and similar shapes
Homework	Watch videos and assess with open-note quizzes	Watch videos and complete worksheets to coincide with each video
Access supports	• Lunch and after-school video availability for students without home access • Digital files available for offline use	Before-school, during-lunch, and after-school video availability for students without home access

GILLETT'S APPROACH

I implemented the flipped classroom in an eighth-grade honors geometry class. Before the flip, my geometry class had a traditional feel—from a brief skill-oriented warm-up to homework review, notes, discussion of definitions and vocabulary, and example problems. However, the routine kept my students from exploring on their own the concepts that I was presenting daily. I wanted to give students more time to apply their knowledge.

I implemented my flip during a unit on surface area and volume. For my video content, I selected Brightstorm (Brightstorm 2013), which featured an educator in front of the camera, in contrast with Khan Academy's (Khan Academy 2013) annotated notes. I chose Weebly (Weebly 2013) to share videos with my students because it was easy to work with. Homework videos introduced the next day's topic, and we used class time to solve rich real-world problems collaboratively by applying concepts from the videos. Students watched the videos as homework and took a brief open-note quiz on the content at the start of the next class. Thus, they would have a strong foundation for in-class explorations. The rest of class time typically entailed launching a rich task and students applying their knowledge together.

Although homework completion increased by 5.4 percent, this improvement required a lot of reminders to students to watch the videos. As with traditional homework, the consequence of not engaging with the videos was a low score on the next day's quiz. Co-author Moore suggested giving the students digital reminders from calendars and something tangible, such as a follow-along worksheet, to better support student engagement. Because my students did not think of the videos as "homework," I expected that, barring technical issues, all my students would watch the videos. Students who experienced technical issues came to class early to watch the videos on their iPods® or similar devices.

Class time during this unit was marked by more student interactions, both peer-to-peer and student-to-teacher, than in a traditional approach. The flipped format allowed me to spend more time with individuals and small groups listening to and probing their thinking. In addition, students led our classroom discourse more often and took increased ownership of their learning. For example, they were more willing to ask for help and contribute key mathematical ideas rather than wait for these to be provided during a homework review.

I checked with my students frequently about their experience with the new routines. One benefit, as students reported, was that they spent less time taking notes in class and more time doing problem solving, a big reason for me to continue working with the flipped classroom. Personally, the most satisfying part of the experience was when a student told me that he did not like the flipped classroom because "I have to think a lot harder. Before, I could just do problems." This student had shown little engagement during class time in the traditional setting. With the change in routines during the flipped unit, he became more self-reliant out of class and more engaged in class.

Not every experience that students reported was positive, however. I was surprised to learn that my students did not like Brightstorm. Toward the end of the unit, they asked me to make my own videos—not because the Brightstorm content was poor, but because I was more familiar to them. This preference relates to Mazur's idea of tailoring education to student needs and allows a more personal interaction with my students. Producing my own content also allowed me to better accommodate mobile users, because I could e-mail video YouTube® links (http://goo.gl/iTzNlT) to the students on request.

MOORE'S APPROACH

During my student teaching, I implemented a flipped classroom approach in five sections of seventh-grade prealgebra. By the time I conducted the research, during spring of my full-year internship, I was comfortable with my previous routine, and both my students and I were ready for a change. One challenge throughout the year had been homework completion, a struggle that made the flipped classroom model particularly intriguing.

In planning for my flip, I selected a visual unit that I thought would be well suited to the video medium: Investigation 3: Scaling Perimeter and Area from the Connected Mathematics Project (CMP) unit "Stretching and Shrinking." I created my own videos using PowerPoint® and VoiceThread© (voicethread.com) to add audio and text notations over the slides. I posted the videos to my class Edmodo® site two days before each lesson. My videos reviewed previous material, introduced new vocabulary for the next day's lesson, and gave a glimpse of the next day's content. I made sure that my teacher personality came through in the videos, and I created handouts to guide my students through each video and help them take notes (go to **www.nctm.org/mt**), to be completed as homework and checked by me the next day. The students used this resource to help them with the next day's activity. I could also check to see who had accessed my class website and the videos.

THE AVERAGE HOMEWORK COMPLETION RATE ROSE; ONE CLASS INCREASED ITS HOMEWORK COMPLETION RATE BY 19 PERCENT.

Throughout the flipping process, I noticed differences in my teaching and student outcomes. Before, class consisted of my reviewing previous material and defining vocabulary words and students taking notes on new material and doing practice problems. Homework was typically finishing problems not completed in class. In the flipped unit, I introduced a task, provided time for student exploration individually and in small groups, and summarized with a whole-class discussion. Doing so allowed me to talk to all my students during the hour. The average homework completion rate of all five classes during the flipped unit rose 13 percent; one class increased its homework completion rate by 19 percent.

Students loved using technology for their homework and enjoyed going home to watch Moore's flipped videos. Students who did not have Internet access at home had to find time to come in before or after school or during lunch or a find a friend who had Internet access to be able to watch the videos. Most students without home access were able to do this regularly.

A familiar look to the Web interface was also an important factor for students. My students enjoyed Edmodo because it resembled Facebook®. Some students mentioned that, because they were not working on problems from a textbook, the activity did not seem like homework.

REFLECTIONS ON THE TWO APPROACHES

After our experiment with the flipped classroom, we found that the overall experience for students and teachers met the goals of increasing student engagement. We had more class time to do meaningful mathematical activities with students. The increase in class time also allowed more one-on-one time to support students in working on higher cognitive demand tasks and exploring conceptual ideas. The discourse in our classes increased both in quantity and quality. The flipped classrooms increased student engagement in the amount and quality of the mathematical work and thinking in class.

LEVERAGING THE BENEFITS OF THE FLIPPED MODEL MEANS MAKING SMART CHOICES ABOUT USING PLANNING TIME AND TECHNOLOGY.

The changes in homework completion highlight two important shifts for students. First, more students were doing mathematical work outside school, and the nature of this work changed. Second, because the use of class time shifted to doing mathematical tasks, nearly all students had opportunities to engage in mathematical problem solving that we had typically relied on homework to provide. Because of the changes to classroom work, unprepared students had opportunities to work with their peers and could engage more readily with problem solving during class time. These two changes related to homework show that the flipped classroom broadened students' opportunities to learn mathematics.

The flipped classroom also increased our access to students' thinking and reasoning, helping us better understand our students and what they were learning. The flipped model allowed more time to interact with students, watch the ways in which they engaged with problem-solving practices, and get a clearer picture of how time spent working on rich tasks in class influenced their knowledge and practices as mathematics learners. This particular outcome strengthened our practice as teachers and made us feel that our investment in setting up the flipped classroom was worthwhile.

STARTING SMART WITH THE FLIP

Using our research, we were able to build a productive flipped-classroom model that we could use in our classrooms. To disseminate the videos, we each chose a website that was familiar to us and our students and was accessible on mobile devices such as smartphones and tablets and for students without home Internet access. Video services such as YouTube and Vimeo®, which are mobile ready, are good choices. Producing copies of videos on DVD and offering office hours at school can support equitable access. Our students' reflections suggest that your own presence as a teacher, either through narrated voiceovers or a camera presence, may be an important factor in the success of the videos. Scaffolds such as worksheets or quizzes are important to help students focus on key ideas and assess what students learned from the homework videos. We hope to continue experimenting with other design variables, such as the content and structure of the supporting worksheets, and whether posing questions for students to ponder and tinker with—rather than presenting worked-out examples—makes a difference.

Our experiences with the flipped classroom took place in the context of a yearlong student teaching internship, during which we had more time and flexibility to get started. In the years since, we have continued to implement these ideas even with a full teaching load because of the tangible benefits for our students—a stronger background knowledge and higher quality in-class engagement.

As with any change in teaching practice, the flipped classroom model means shifts in how we plan for classes and how we select mathematical tasks. The flipped classroom adds a significant technological component into the mix as well. Getting started on leveraging the benefits of this model means making smart choices so as not to saturate one's planning time with handling the technology rather than thinking about the mathematics content we want our students to learn.

A good place to begin is to select a unit that lends itself well to the online environment, such as two-dimensional geometry or function transformations, and begin with a basic set of tools that are easy to use, such as PowerPoint® or a camera trained on a whiteboard. School media specialists or even students in a media arts class can be excellent sources of support in creating content and making it available online. Using or adapting existing videos might also be a good entry point, with a goal of creating your own in the future. Mathematics departments might also wish to collaborate on a unit, with different teachers responsible for producing videos for different lessons. Although tailoring the videos to your class and context is important, many existing resources are available.

The flipped classroom model has great potential for improving students' mathematical knowledge and providing time to engage in high cognitive demand tasks that embody the recommendations of the Common Core Standards for Mathematical Practice (CCSSI 2010).

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Editor's note: This article was submitted in response to Call for Manuscripts: On the Front Burner, which explores provocative current issues in mathematics education.

AMANDA J. MOORE, lovea@pennfield.net, teaches seventh-grade mathematics at Pennfield Middle School in Battle Creek, Michigan. She is interested in the use of technology to teach high cognitive demand tasks and in student discourse in middle school classrooms. **MATTHEW R. GILLETT,** mgillett@armadaschools.org, teaches eighth-grade mathematics and first-year algebra at Armada Middle School in Armada, Michigan. His interests include applying technology to mathematics curriculum, teaching geometry through conceptual applications, and teaching students how to reason and communicate mathematics. **MICHAEL D. STEELE,** steelem@uwm.edu, is an associate professor of mathematics education at the University of Wisconsin–Milwaukee. His interests include the development of mathematical knowledge for teaching, the design of teacher education and professional development, and discourse and argumentation in high school classrooms.

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An activity sheet is available to teachers as a Word document that can be copied and edited for classroom use; go to **www.nctm.org/mt**.