FLIPPED CLASSROOMS AND SUPPLEMENTAL INSTRUCTION: MATHEMATICS ENGAGEMENT THROUGH MULTIPLE MODALITIES

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Introduction

Recent research (Hendrick, Opdenakker, & Van der Vaart, 2023) and anecdotal evidence from conversations with collegiate faculty suggests students are less engaged in academic settings since the shutdowns from the COVID-19 outbreak. Additionally, flipped classroom (FC) instruction is on the rise since the pandemic (Divjak, et. al., 2022). We (two of the authors) began using FC instruction recently as we searched for ways to strengthen student engagement in mathematical content, particularly in gateway mathematics courses (such as College Algebra or Precalculus). Additionally, our institution has a robust Supplemental Instruction (SI) department to support student learning. We saw potential to improve student engagement in our mathematics courses by using flipped classroom and supplemental instruction. In this paper we document some of our

experiences, successes, and challenges in the hopes that readers may find useful ideas that may strengthen student engagement in their own classes.

Background and Definitions

Kitchings and Davidson-Rossier are mathematics faculty members, and Hefner, Daniel, and Poston are part-time student SI facilitators at the University of North Georgia. Both faculty members have partnered with SI facilitators at our institution. We have also made attempts to use flipped instruction in the past two years.

We purposefully take a broad definition for FC instruction. We define FC instruction as instruction that occurs in such a way that delivers lecture-type content outside of class, thus providing more time in formal class settings for higher-order thinking activities and problem solving with more student-instructor interaction. Flipped classroom instruction may be partial (by selecting some or many topics to teach with traditional lecture mixed in) or full (delivering all course topics from a flipped approach). A common component of FC instruction is the assignment of recorded video instruction outside of the scheduled class time.

Supplemental Instruction is defined as "an internationally recognized academic assistance program designed to help students navigate historically difficult courses through additional exposure to, and practice with, course material in a group setting" (UNG Supplemental Instruction). Supplemental Instruction serves students in traditionally difficult or gateway courses with high DFW rates (grades of D, F, or a withdrawal grade) such as College Algebra (see also Anfuso et. al., 2022)

Flipped Classroom Instruction

We (Kitchings and Davidson-Rossier) chose to move to FC instruction for several reasons. We questioned, "How do students learn if they are not engaged? How do we help students focus on the content?" As mentioned above, we wanted to try to create an environment to strengthen student engagement. We also wanted to try to create learning environments that minimized distractions from outside of class (i.e., inappropriate use of cell phones or artificial intelligence technologies). We wanted to foster and encourage more student-to-student interactions and discourse in the classroom about the mathematical content. We also wanted to be able to better monitor students and discourage academic misconduct while working on mathematics problems. In the FC model, students had direct access to the instructor while working problems, which encourages appropriate use of resources to solve them.

How would an instructor begin the process of flipping their classroom? There must be a way to communicate necessary content outside of the classroom. In most cases this is accomplished with video instruction and accompanying note-taking guides (NTGs). These videos may be created by the instructor or instructors may link to pre-existing videos from the web. We used a combination of both instructor-generated, publisher-generated, and public videos available on the web (such as from YouTube or Khan Academy). See

Kitchings (2020) and Hartfield (2020) for more advice on creating quality instructional mathematics videos.

In Kitchings' flipped Summer 2023 class, the Ratti et. al. (2023) *Precalculus: A Unit Circle Approach* with MyLab Math contained high-quality videos and accompanying NTGs that directly aligned with each section of the text. The NTGs served to help students focus on the video instruction. An anecdotal search of newer titles from Pearson suggested that updated textbook versions (2024 and beyond) in MyLab may also contain full sets of NTGs and accompanying videos. If an instructor's text does not contain these resources, instructors may need to create their own NTGs based on the videos they assign to students.

We assigned NTGs and accompanying videos for completion outside of class. The students then attended class where they were presented with problems to solve that were related to the content delivered through the videos and NTGs. Students also had time to work "homework problems" during class time. The FC instruction model requires careful planning to coordinate the NTG and video delivery with the face-to-face meeting time. The structure of the in-person class also helped encourage student-to-student participation and discourse rather than a passive approach from students (i.e., more active learning). The Vanderbilt Center for Teaching article contains additional depth of discussion about flipping the classroom (Brame, 2013).

Our brief experiences using FC instruction led us to several recommendations for moving forward. We learned that the instructor should resist the temptation to continue full-class lectures with the flipped model. A traditional class lecture undermines the intent of the flipped approach. Small, mini lectures in class are appropriate to review content as deemed necessary or as student needs demand.

The instructor must also create an environment in the class that helps students to embrace the FC instructional model from day one of the course. We found that some (or many) students may have misconceptions about what instructors expect from this model. The instructor should create detailed expectations for students and communicate those expectations with clarity. Additional reminders may be required weekly. Students need to understand what they need to do outside of class and why. Students should also understand that content mastery is not necessarily expected outside of class as some students may claim, "I cannot learn mathematics from a video." Instructors can affirm students' concerns while emphasizing the importance of engaging with the video's content and the NTG as a means of preparing for learning inside the classroom.

We compiled a list of observations and recommendations for consideration when using FC instruction:

- We saw the advantages of establishing clear classroom routines and norms for students to follow consistently from day one. Students responded with more consistency with the presence of such routines.
- Remind students (regularly) the videos are of good quality and are worth their time and investment. The instructor may use small, mini, or micro lectures to help bridge the video instruction with the in-class task or activity.
- The instructor's presence and demeanor are also important. Welcome student complaints and use them as opportunities to strengthen understanding and communication between instructor and students.
- Be attentive to the lengths of videos assigned. Provide clear expectations about completion of the note guides (possibly including them as graded tasks for additional accountability).
- We recommend starting flipped instruction in small increments. It is easier to flip one lesson, topic, or unit at first before moving the entire class into a flipped model.

In addition to using FC instruction, we also partnered with our institution's Department of Supplemental Instruction to try to strengthen content engagement outside of class.

What is Supplemental Instruction?
Supplemental Instruction pairs "what to learn" with "how to learn" through collaboration between peers and interactive activities. Each week, the facilitator holds three 50-minute sessions centered on students' needs in the class. Two sessions are preplanned, and the third is less structured and guided by the needs of students. The third session still follows the SI model of collaboration and is distinct from individualized tutoring.

A common misconception is that SI is equivalent to tutoring. Supplemental Instruction focuses on more content overview and understanding as a group whereas tutoring is more individual or one-on-one. Supplemental Instruction is different from tutoring because of the higher focus on collaboration versus individuality. Supplemental Instruction emphasizes collaboration over individual tutoring, aiming to enhance students' overall understanding of the subject to strengthen independent problem solving.

The University of North Georgia is accredited by the International Center for Supplemental Instruction. Accreditation requires rigorous guidelines including training, observations, and a strong focus on planning. At our institution, SI facilitator training begins two days before the semester where the facilitators learn about instructional strategies, techniques, and methods to plan and run a session. These trainings are also collaborative and interactive totaling about 16 hours before the semester begins. After the semester starts, facilitators are expected to participate in hour-long professional development trainings every other week. Each facilitator is also required to observe two different facilitators during the semester. During the observation process, facilitators will take notes of the entire session and then mentors (experienced facilitators) will provide feedback to the facilitators. Mentors are also required to observe and give feedback to at least two facilitators every week to ensure that each facilitator follows the SI model. Because facilitators only must plan two of their three sessions, they are expected to plan them in enough detail that a

different facilitator could come in and run their session. Strong planning ensures consistency and quality across sessions for facilitators and students.

In general, across all University of North Georgia courses (not only mathematics) partnered with SI, we observed a 0.39-point increase in grade point average (GPA) for students who attended one or more SI sessions (institutional data). For students who attended seven or more sessions, we saw an increase of 0.7 in GPA. On average, UNG institutional data showed SI lowered the DFW rate by 15.93%. Students who attended SI sessions attended (on average) about 5.83 sessions. The SI facilitator offers three sessions every single week for 15 weeks. Students attending at least seven of those sessions experience a significant increase in their GPA – over half a letter grade higher. For mathematics courses, students see a 0.23-point increase in GPA for those who attend one or more sessions. For those who attend seven or more sessions, we see an increase of 0.63 in GPA. On average, SI lowers the DFW rate in mathematics courses by 13.82%. For mathematics classes served, the student participation rate was approximately 29% with an average attendance of 6.07 sessions per student.

Vignette: Daniel's In-Person Experiences as a Student and Facilitator

During my semester as a Precalculus student, I was introduced to SI and decided to attend my first session. I enjoyed the session and continued attending for the rest of the semester. Not only were the sessions helpful in allowing me to practice and master difficult class material but they included fun and engaging tasks that motivated my attendance. These activities inspired me to dream up creative ways to study on my own. For example, one of my favorite activities was when we thought of everything we could remember from a previous lecture and 'brain-dumped' everything on a whiteboard. I continue to use this activity during my own study time and have built on it. I also discovered that being able to collaborate with my peers through these student-led sessions created a welcoming environment that invited students to work together to strengthen our understanding of the material, which allowed us to become more independent learners.

After successful completion of Precalculus as a student, I became an SI facilitator the next semester. My experience with FC instruction and SI as a student gave me insight into helping students through challenging topics as an SI facilitator. While I was an SI facilitator for Precalculus, I saw FC instruction be a powerful tool for students to have a better grasp on the material and be confident in their knowledge of it. After surveying students who consistently followed along with the pre-lecture introductory videos and completed the corresponding note taking guides, the consensus was that they enjoyed implementation of this style of instruction because it jogged their memory of certain concepts they saw in previous math courses and gave them a general idea of what concepts they were to be familiar with for the next class. Students who allowed flipped instruction to help them learn more efficiently came to class ready for the next class, and it gave them the confidence to participate and engage in class discussions. There were a few students, however, who did not consistently complete the pre-lecture videos and note-taking guides. As a result, they came to class the next day without the necessary background to complete the tasks at hand.

During my semester as an SI facilitator, I was able to incorporate fun and engaging activities into students' study time while still delving into challenging course content. One of my favorite activities that I planned for students was “Knowledge Pong.” In this activity I wrote questions about either Precalculus concepts or practice problems on slips of paper and placed them into cups. Students aimed and shot a ping-pong ball into the cup. Those who correctly answered the question in the cup scored a point. At the end of the activity, we tallied up the points to determine a winner. Students enjoyed this activity as a more active learning approach that offered them a more engaging outlet. As a facilitator, I recognized topics that I struggled with as a student and included them in my sessions to strengthen student confidence with those topics. I saw the importance of building relationships with students inside and outside the classroom to show them my support and encourage them to take advantage of SI as a fantastic resource to maximize their potential. Establishing rapport with my professor was another vital component during my time as a facilitator to maintain consistent communication of students’ needs and to receive feedback on how to best integrate certain topics into my sessions. This collaboration fostered a team dynamic, where my professor supported me as an instructor, and I served as an advocate for students, providing insights into their areas of struggle.

Vignette: Poston’s Online Facilitator Experiences

I have been an online SI facilitator for three semesters facilitating Calculus, College Algebra, and Precalculus. I have also been a mentor with the UNG SI program for a semester. The format of these courses was asynchronous online. Facilitating these SI sessions online involved adaptation and flexibility. The first adaptation is the medium used to hold sessions. For online facilitating, Zoom was utilized. A USB-C drawing tablet was a crucial tool as well. Online math sessions were made possible by using the Zoom whiteboard feature along with a drawing tablet. The drawing tablet provided maximum flexibility to annotate mathematical expressions and equations.

There are many strengths when facilitating online SI sessions via Zoom. It is rare for students in asynchronous classes to engage with their professor or classmates. Students in online classes often feel very isolated and do not experience the same type of community that in-person students have with their classmates. The online facilitated sessions engender engagement and community for the students. Supplemental Instruction sessions provide students with valuable time with their peers while also practicing the class content. This unique experience promotes engagement and encourages students’ success.

Holding SI sessions for online students also lets them practice the content in a safe space. Online classes deliver content and require students to practice only through homework with limited opportunities to receive quality feedback. The SI session allows students to make mistakes in a low-stakes environment and receive feedback in real time. The interactive component of a class is extremely important and can be left out in online classes. The presence of an SI facilitator in an online course promotes productive discourse and can lead to students learning mathematics rather than memorizing procedures.

Another strength of online SI sessions is that they are generally more accessible. An online SI session does not require travel to a physical location and requires minimal time to join. Students may join these sessions from anywhere with internet access, which allows students more schedule flexibility. The online accessibility of SI fully allows students to reap all the benefits that it offers.

The second adaptation of online SI sessions from in-person sessions is the activities. Supplemental Instruction activities are usually 10-to-15-minute activities in which students are encouraged to collaborate with one another in innovative ways. Some activities are difficult to adapt, but others lend themselves well to an online format. Consider the example of the "Pathfinder" activity below (Figure 1). I found this activity worked well in my Zoom sessions.

START	$G(x) = x^3 - 2x^2 + 18x + C$ Next Question	$G(x) = \frac{e^{4x}}{4} + 32x + C$ Next Question	$G(x) = x^2 - 3x^3 + C$ Next Question
$G(x) = 6x - 4$ Next Question	$G(x) = \frac{e^{4x}}{4} + 32x^2 + C$ Next Question	$G(x) = \frac{sin(2x)}{2} + cos(x) + C$ Next Question	$G(x) = \frac{2x^{5/2}}{5} + C$ Next Question
$G(x) = e^{5x} + 16x + C$ Next Question	$G(x) = -2sin(x) - cos(x) + C$ Next Question	$G(x) = xln(x) + C$ Next Question	$G(x) = sin(x) + C$ Next Question

Figure 1: Pathfinder Activity Example

I created this activity with inspiration from some of my favorite activities I have seen in my own math classes. This activity requires a PowerPoint and involves a grid of 12 boxes with hyperlinks. Students begin by clicking the "START" hyperlink which takes them to their first question. They solve the problem on a sheet of paper and dictate their steps to me while I write them on the Zoom whiteboard. When the student obtains an answer, they look at the adjacent boxes and click the "Next Question" hyperlink under the answer that is theirs or most resembles theirs. The hyperlinks link to other slides that either present the next question or a slide saying, "Sorry but that is not correct." Students found this activity as a fun and engaging way to solve problems and it was one of their favorite activities.

A strong online implementation of SI sessions requires regular collaboration with the instructor of record. Regular collaboration ensures that the SI facilitator knows the scope and sequence of the course topics and content timeline. Weekly or biweekly meetings

between facilitators and professors are crucial to making SI sessions as effective as possible.

Of course there are some challenges to this modality of learning. Online SI sessions do not always go according to plan, and students do not always respond the way we expect. There can be high or low participation in online sessions depending on the students in the classes. Students with high motivation typically attend SI sessions regularly, whereas students with low motivation may rarely attend. This all depends on the students' attitudes towards the class. Professors can provide extra motivation and encouragement for students to show up for a specific number of sessions. This helps with engagement and incentivizes students to attend sessions. Students who do attend sessions usually find them helpful and enjoyable. Many students develop intrinsic motivation to continue attending sessions as they realize the benefits of SI.

Conclusion

Student engagement levels since the pandemic have been in decline. Many instructors have searched for ways to better support student success in mathematics classes. We began exploring Supplemental Instruction and Flipped Classroom instruction as two ways to promote better student engagement and student accountability. We see potential for both, and we hope our descriptions and vignettes may be useful for other faculty who may wish to explore these methods.

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