FLIPPED LEARNING IN A PROGRESSIVE MIDDLE SCHOOL SCIENCE CLASSROOM

by

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ABSTRACT

With a variety of digital learning resources available to students anywhere at any time, it is possible to rethink how the classroom time and space is used. In simple terms, flipped learning moves direct instruction learning activities such as lectures and teacher explanations that have traditionally been in the classroom space into the homework space, where these lessons take the form of teacher-prepared or -curated videos. Classroom time and space is then made available for small group and independent active learning, the types of activities that have traditionally been done outside of school. This study investigated the effects of flipped learning on student comprehension, engagement, and collaboration. The study also examined how this newly available class time was utilized by students and the teacher, and how flipped learned affected student-teacher relationships. Comprehension was assessed through quizzes and open-ended concept modeling activities. Engagement and collaboration were assessed through surveys, student interviews, and qualitative teacher observations. While there were no major differences in comprehension or engagement, students were found to collaborate more organically and flexibly. Some students used the greater class time to slow down and go deeper on assignments, while some disengaged from effective collaboration in this context. Student-teacher relationships became more robust with the teacher knowing more about students as learners and individuals, and more able to address misconceptions and answer individual questions.

INTRODUCTION AND BACKGROUND

In the fall of 2018, I took a position teaching middle school science at Synergy School in San Francisco, California. Synergy is an independent progressive school with a TK-8 enrollment of 189 students in the 2018-2019 school year, with only 75 students in the middle school. Of the total enrollment, 47% are students of color, and 30% receive financial aid with awards ranging from 5% to 90%. My previous assignment was teaching seventh grade science at Hoover Middle School, a public school in San Francisco Unified School District with an enrollment hovering around 1,000 students throughout the nine years I taught there. At the time I left Hoover, 92% of students were students of color, 67% were socioeconomically disadvantaged, 15% were English language learners, and 9% were students with disabilities. Moving to Synergy School represented a significant change in teaching context and teaching practices for me.

After teaching at Synergy for a couple months, an interesting instructional problem emerged. My science classes were mixed grade-level (6-8) and met twice per week in 100-minute blocks. There was some variability in when they met during the week as well. The first block met Mondays and Thursday, the second block met Tuesdays and Fridays, and the third block met Wednesdays and Fridays. Throughout most of my time teaching in a public middle school in San Francisco, I tailored my instructional approach under two key assumptions which no longer applied in this new context.

The first assumption was that I would see each class nearly every day, and for a standard 45- to 50-minute class period. The class-time I had to work with at Synergy School was less than I was accustomed to at only 200 minutes per week, compared to the

250 minutes of class-time I worked with in the public school setting. Additionally, with each class only meeting twice per week, and with the implicit goal of each class section making more or less the same progress during each class session, the 100-minute blocks needed to be well-planned and well-managed to make the most of the available time. This meant that if something in the lesson did not quite work, there was little space or opportunity for "fixing it tomorrow." I found that the infrequent class sessions also magnified a phenomenon that is likely familiar to many teachers: not every class receives the same instruction through both intentional and unintentional actions by the teacher, and not every class has the same needs for instruction. A teacher may intentionally differentiate for each class section and may correct errors that emerge through each iteration of a lesson. Unintentional differences may have to do with teachers being humans who change moods, get tired, get excited, make mistakes, forget things, and come up with new ideas each time they repeat a lesson. In my irregular teaching schedule at Synergy, however, I found it particularly challenging to deliver similar lessons across the class sections, and to appropriately differentiate and adjust for the various progress each class made. While some of these concerns could partially be addressed through careful planning and time-management on my part, I believed there were additional, more transformational opportunities presented here.

The second assumption that guided much of my public school teaching was that the vast majority of learning needed to take place in the physical space of the classroom and in the temporal space of the class period. In my experience, students in my classes were unlikely to do homework outside of school, particularly the non-mainstream (non-

white, non-native English speaker, socioeconomically disadvantaged) students whose achievement I was most concerned about supporting. If my mission was to close the achievement gap, assigning traditional homework would only serve the opposite purpose. At my new school, however, students were far more likely to complete homework. In fact, students and families expect homework at Synergy School. As part of the school's agreement system that forms the foundation of the Synergy philosophy, students agree to "participate academically," an agreement that includes completion of homework. When students do not keep this agreement, an incremental system of support is put in place that culminates in a "contract for change" between the student, the school, and the family to get them on track with meeting the agreement. So, at my new school, the assumption around homework needed to be reversed: students would do assigned homework and would be held accountable for it.

The instructional problem that emerged, then, was this: How could I arrange in- and out-of-class work to best utilize the time and resources available? Furthermore, how could I effectively differentiate in a mixed grade-level setting? And finally, how could I make the primary content and instruction students receive somewhat consistent, while still making time to address misconceptions and questions, and provide additional skill practice and collaboration where needed? The intervention I identified to address these problems is flipped learning.

To determine the effectiveness of a flipped learning model, I posed this primary research question: How does a flipped learning model influence student engagement, comprehension, and collaboration? As secondary questions, I wanted to know how the

use of a flipped learning model would affect student-teacher relationships, and how the flipped model would affect the use of class time by students and by the teacher.

CONCEPTUAL FRAMEWORK

Much of the present understanding of flipped learning is based around the work of two Woodland Park, Colorado chemistry teachers, Jonathan Bergman and Aaron Sams. When the teachers came together in 2006, both were using a traditional instructional format that utilized whole-class direct instruction. Facing the problem of how to reteach lessons for students who had been absent, Bergman and Sams turned to software that allowed them to record and annotate lessons that could then be posted online to be accessed asynchronously by the target students. They found, however, that the video resources were also being used by students who actually had been in class, but for the purpose of further review and reinforcement. This led to a realization by the teachers that this was a tool with which to radically reimagine how classroom time and space were used. So convinced were Bergman and Sams of the effectiveness of the approach that neither teacher has used whole-group, in-class direct instruction ever since first developing the model (Bergman & Sams, 2015; Tucker, 2012). Bergman and Sams define flipped learning thus:

> The idea of the flipped classroom is really quite simple. Direct instruction is done though video, or some other digital learning object, which students can use individually before they come to class. This time shift allows the teacher to use class time for work that either is better done as a large group or requires individualized attention by the teacher. That's it. The flipped class, in brief, is direct instruction delivered to the individual outside of class, so there is more strategic use of in-class time for group work and individualized attention. (2015, p. xii)

In this definition, a key feature of flipped learning that is highlighted is freeing up teacher resources to make space in the classroom for individualized student attention. The less time that must be devoted by the individual teacher to addressing a large group of students, the more time that is available to working one-on-one or in small groups. In the flipped model, Bergman had the time to interact with every student every day. He also noticed that while in a traditional model the more outgoing and engaged students were the ones asking most of the questions, in the flipped model where he was able to spend more time with struggling students, those struggling students began asking more questions and worked through challenging problems in class while advanced students had more freedom to learn independently. Bergman found that as students acclimated to the model, they began asking better questions and thinking more deeply about the content. Additionally, Bergman noticed that he could more easily and more quickly uncover individual students' misconceptions and help students to change them (Tucker, 2012).

The Flipped Learning Network, an organization of educators born out of the work of Bergman and Sams (who also serve on its board), offers a definition that portrays the flipped learning classroom as a space that actually empowers students:

> Flipped Learning is a pedagogical approach in which direct instruction moves from the group learning space to the individual learning space, and the resulting group space is transformed into a dynamic, interactive learning environment where the educator guides students as they apply concepts and engage creatively in the subject matter. ("The Four Pillars of F-L-I-P™," 2014)

Here, the idea is that flipped learning makes space for students to engage in the higher levels of Bloom's taxonomy of learning (and its revised version), suggesting that in the flipped learning classroom, students are encouraged to apply and create. This draws a

contrast to the direct instruction that is moved outside of the classroom space in which students generally engage in the lower levels of the taxonomy of remembering and understanding (Anderson, Bloom, & Krathwohl, 2001; Bloom, 1956).

The Flipped Learning Network further defines the approach with its Four Pillars of F-L-I-P™ that outline what its members see as they key features of flipped learning: flexible environment, learning culture, intentional content, and a professional educator. The first pillar stipulates that a flexible environment is flexible in its arrangement of physical space to accommodate the needs of specific lessons or units as well as to support group work or independent study. Flexible environments are also flexible in their expectations of student timelines and in their assessments of student learning. The second pillar, learning culture, shifts the focus of learning activities away from the teacher and to the student such that students are actively involved in tasks that are personally meaningful, and are differentiated such that they are accessible to all students. The third pillar, intentional content, calls on the teacher to mindfully curate content for asynchronous out-of-class direct instruction (usually in the form of videos) that will help students develop conceptual understanding and procedural fluency that can be applied during classroom time. The final pillar, the professional educator, acknowledges that the teacher's role in a flipped classroom can be more demanding than in a traditional one. The teacher must continually monitor students as they work, provide feedback relevant in the moment, and conduct ongoing formative assessments. They must be available to students in real time. They must reflect continuously on their practice, collaborate, be

accepting of constructive criticism, and tolerate controlled chaos in their classrooms ("The Four Pillars of F-L-I-P™," 2014).

In their survey of flipped classroom research, Bishop and Verleger (2013) point out that flipped learning "represents a unique combination of learning theories once thought to be incompatible—active, problem-based learning activities founded upon a constructivist ideology and instructional lectures derived from direct instruction methods founded upon behaviorist principles." They point to student-centered learning theories such as cooperative learning (Johnson, 1984; Rottier, 1991; Sharan, 1990; Slavin, 1991), collaborative learning (Smith & MacGregor, 1992), peer-assisted learning (Ehly & Topping, 1998), experiential learning (Kolb, 1984), problem-based learning (Barrows, 1996; Hmelo-Silver, 2004), and active learning (Michael, 2007; Prince, 2004) that all connect to Piaget's theory of cognitive conflict (1967) and Vygotsky's zone of proximal development (1978) to support the understanding of the flipped learning in-class space as a constructivist space that facilitates and requires human interaction.

Bishop and Verleger restricted their review of available research with the definition of a flipped classroom as one where "out-of-class activities must include required video lectures; in-class activities must be required, and must involve interactive learning activities—specifically, the primary in-class component could not be lectures." They found that most studies reported on student perceptions of an instructional change to flipped learning, and that these perceptions were relatively consistently positive with a few students in each study who strongly disliked the change. Students tended to watch supplied video lectures whether they were required or not. One study in the review noted

that college students who were supplied with optional video lectures came to class much better prepared than when they were only supplied with textbook reading (de Grazia, Falconer, Nicodemus, & Medlin, 2012). While students preferred in-person lectures to video lectures, they also liked interactive class time more than in-person lectures (Toto & Nguyen, 2009). Students preferred shorter videos over longer videos (Zappe, Leicht, Messner, Litzginer, & Lee, 2009).

Bishop and Verleger found two studies that met their definition of flipped learning and that examined student learning outcomes. Moravec, Williams, Aguilar-Roca, and O'Dowd (2010) conducted a brief study in which three lectures given in an introductory biology course were modified to narrated PowerPoint videos. Students were required to watch the videos before class and complete a worksheet. Then, in-class time was structured as alternating ten-minute mini-lectures and five- to seven-minute active learning exercises. This led to a 21% performance increase on exam questions related to the concepts introduced in the videos. This instructional format, however, is only somewhat related to flipped learning as a majority of in-class time was still utilized for direct instruction through lectures.

A study with more compelling results was conducted by Day and Foley (2006) in a senior-level computer interaction course with concurrently taught experimental and comparison sections of the course. Students in the experimental section watched narrated presentations outside of class and participated in interactive learning tasks in class. Students in the flipped environment scored higher on all homework assignments, projects, and tests.

It is important to note that the results of the survey by Bishop and Verleger may have limited application in this project as all studies they examined save for one were performed in postsecondary settings, with the exception being performed in a high school setting; no studies at the middle school level were examined. Nonetheless, they found broad evidence in the studies surveyed that students had positive perceptions of flipped learning practices, and some limited evidence that flipped learning yielded academic performance gains.

Noting the dearth of research on flipped learning in the K-12 sphere, Winter (2018) studied the performance and motivation outcomes of flipped learning in a 6th grade social studies course at a K-12 private school in Hawai'i. In particular, Winter sought to identify the relationship between motivation and performance in the flipped learning course. Winter highlights the cognitive transitions middle-grade students go through and emphasizes a number of studies that have shown the usefulness of differentiation and instructional technology to meet the diverse needs of this student group. The findings of the study indicated a correlation between students' perceived effort and their performance in the course. That is, students who felt engaged and motivated performed better. Interestingly, though, Winter points to findings that suggest "technology-based content perceived by students as requiring limited effort can motivate and improve performance… The implications are to design learning spaces that motivate and maintain engagement" (p. 181). Achievement and self-reported effort gains were highest among middle performers. Winter states that the study suggests "flipped learning is a model approach for middle school," (p. 181) but stresses that the approach is most

effective when implemented with age-appropriate strategies, specifically differentiated instruction" (p. 181) as outlined in the extensive literature on differentiation (Tomlinson, 1999, 2001; Tomlinson & Moon, 2013; Wormeli, 2018).

While limited, research into specific best practices in flipped learning is emerging. Slemmons et al. (2018) examined how different lengths of videos in a flipped middle school science setting would affect student engagement and attitudes, and how different lengths of videos would affect both short- and long-term retention. Over the two-year study, two groups of students participated in two instructional units designed as a flipped learning environment under the definition offered by Bishop and Verleger (2013). Each group was given the same video content, but the videos given to one group were digitally split in half so as to provide two separate shorter videos. These videos were considered to be "short" while the unsplit videos were considered "long." No specific video lengths were identified by the authors of the study. Each student group experienced one flipped unit with short videos, and one with long videos. Slemmons et al. found that short-term retention as measured by quizzes immediately following the videos was not significantly different between short videos and long videos. Long-term retention as measured on unit tests for each student group overall also did not show significant differences between short videos and long videos. When looking at sub-groups, however, the study found that long-term retention for male students and for students with learning differences was higher when those students had viewed shorter videos. Additionally, students self-reported that they were more engaged, focused, and had a perceived higher retention when they viewed shorter videos. In their discussion of these findings, the

authors note that “students at this age may have immature abilities to organize the complex content information presented in a long video, since the content of the long videos may be too complex to compress into a reasonable way” (pp. 476-477). The authors elaborate that shorter videos may aid in chunking of memory components to better serve schema construction (Chase & Simon, 1973), and that shorter videos may also reduce the cognitive load required of the student (Mayer & Moreno, 2003).

Bergman and Sams (2015) recommend that teachers make their videos interactive so that “students are actively engaged with the content and have something to do as they watch” (p. 18), and so that the videos do not simply become “a high-tech version of an antiquated instructional method: the lecture” (Ash, 2012). To extend this line of thinking, Lim and Wilson (2018) state that it is the active learning component of the flipped classroom that contributes to higher learning gains, and that this active learning “requires students to self-learn the content within their individual learning spaces so that they are ready to apply what they have learned to solve problems independently and collaboratively in class” (p. 380). Lim and Wilson therefore offer that embedding questions into videos that students are required to answer is an effective way to engage students in active learning in the individual learning space. They identify that questions or comments can be embedded by teachers into videos for three general purposes: (1) to enhance students’ learning of the information presented in the video, (2) to assess students’ understanding of what they are watching, and (3) to give instructions while students are watching the video. A variety of online tools are available that enable teachers to trim, crop, and embed questions into publicly available videos from sites like

YouTube, Khan Academy, Vimeo, etc. Additionally, software such as Camtasia can be used by teachers to record and edit videos with the inclusion of embedded questions that can then be uploaded publicly or to learning management systems (LMS) that will track students' viewing of videos and responses to questions, and that students are likely already using in their schools to access other class content, due dates, grades, and the like. Bergman and Sams (2015) note that videos should be easy for students to access, and that hosting videos through an LMS is one simple way to do this. For each question teachers consider embedding into videos, Lim and Wilson (2018) ask teachers to think about (1) What is the purpose of embedding this question? (2) How does this embedded question increase student engagement or enhance student learning? and (3) Will it enhance—or break—the students' flow of thoughts in relation to the idea presented in the video? They highlight that embedded questions should not "mainly assess whether student was paying attention to the video" (p. 385), but instead should actually serve the purpose of enhancing learning.

It is important to note that my use of flipped learning approaches is intended to integrate with Synergy School's philosophy of progressive education. While a history or critique of progressive education is beyond the scope of this project, some definitions are useful. The school's stated mission is "to nurture the intellectual, creative, and emotional potential of every child in a community dedicated to diversity, inclusion, and social justice." In articulating how that mission is carried out, Synergy describes its approach to progressive education as "student-centered and developmentally appropriate" and "responsive to the needs of our students' emotional, social, academic, cognitive, and

physical development.” Synergy further defines how students learn by explaining that “students engage in meaningful hands-on projects that require sustained inquiry, communication, collaboration, and problem-solving. They make choices about how to work and what to create to demonstrate understanding and knowledge” ("Progressive Education," 2019). Ultimately, flipped learning is but one strategy that I believe will help to realize this philosophy.

METHODOLOGY

The purpose of this study was to determine the effects on student engagement and content retention of implementing a flipped learning unit in a mixed-age middle school science course. The research methodology for this project received an exemption by Montana State University’s Institutional Review Board and compliance for working with human subjects was maintained (Appendix A). The variety of data collection tools used to answer the questions of this project are outlined in Table 1.

Table 1
Data Triangulation Matrix

Data Source	Questions		
	Focus Question: How does a flipped learning model influence students’ engagement, comprehension, and collaboration?	*Secondary Question:* How will the flipped model affect student-teacher interactions and relationships?	*Secondary Question:* How will the flipped model affect the use of class time by students and by the teacher?
Unit Survey	X	X	X
Modeling Rubric	X		
Subunit Quizzes	X		
Interview Questions	X	X	X
Teacher Observations	X	X	X

Students from three separate sections of the course participated in this study. Data collection began in January 2019 prior to the flipped learning treatment unit and ended in May 2019. Throughout the study, 74 students in grades six through eight were exposed to one non-treatment unit and one treatment unit; 63 students and their families consented to participation in this study and their data is included here. Of the 63 participants, 37% are students of color and 25% have identified learning differences.

Both treatment and non-treatment units utilized curriculum developed by San Francisco Unified School District (SFUSD) and the Stanford Center for Assessment, Learning, and Equity (SCALE) at Stanford University. Units from this curriculum were selected as a way to control the study by keeping the units relatively consistent in structure, organization, and presentation, thereby minimizing the effects of curriculum on study outcomes. Each unit was designed to integrate NGSS middle school standards in the three dimensions of: disciplinary core ideas, science and engineering practices, and crosscutting concepts; to follow the BSCS 5E instructional model of engage, explore, explain, elaborate, and evaluate; and to explicitly call on students to work collaboratively in groups of four with rotating assigned roles. These rotating assigned roles consisted of a facilitator who was responsible for ensuring the group's task was completed; a recorder/reporter who was responsible for keep complete notes and sharing out to the whole class; a resource manager who was responsible for managing materials, equipment, and supplementary resources; and a team captain who was responsible for ensuring other group members tended to their roles, that the group worked together, and

who would fill in for any absent group members. This curriculum also identified key group work behaviors in which students received instruction at the beginning of the year.

The non-treatment unit took on disciplinary core ideas related to waves, focusing on general wave characteristics and behaviors and specific characteristics and behaviors of mechanical waves and sound waves. The unit also called on students to demonstrate their understanding at multiple points through modeling. Direct instruction for tasks and for content was delivered through Google slides presented to the class in live lecture and discussion. These slides were also posted to PowerSchool, Synergy School's LMS, so that students could access these slides during or after class. Students were additionally provided with a student book for each lesson that contained detailed directions for how each group would complete its task(s). One of the rotating group roles, the facilitator, had the explicit responsibility of leading their group through the tasks as written in the student books. Lectures and discussions constituted 25-50% of in-class time. Each explore lesson in the 5E cycle involved an assigned reading for students to complete as homework, and in-class lecture and discussion that typically lasted 30-45 minutes. Class time not used for directions, lecture, or discussion was utilized for small group and individual learning tasks. Routine homework consisted of completing tasks that were not completed in class, independent science reading through Newsela, and weekly self-assessments. Students having assignments to complete as homework that were begun in class was common.

The treatment unit dealt with disciplinary core ideas related to human impact on Earth's climate. As in the non-treatment unit, this unit called on students to demonstrate their understanding at multiple points through modeling. Previews of each lesson and

basic instructions were recorded in a video of less than five minutes that was uploaded to PowerSchool before the lesson. Students were assigned to view this video before class. The first five to ten minutes of each class were used to review the day's agenda and to take questions regarding the day's tasks. Slides similar to those used in the non-treatment unit were presented as visual aids. These slides were also posted on PowerSchool for groups and individuals to access independently. The remainder of class time (approximately 90 minutes) was utilized for small group or individual learning tasks. As in the non-treatment unit, facilitators in each group held the responsibility of leading their groups through tasks as written in the supplied student books. Groups had access to videos uploaded to PowerSchool for review as needed. During the small group and individual work time, I regularly circulated around the room to answer questions, pose questions, and offer guidance. If the same question came up across multiple groups, I would briefly call the class together for discussion.

Videos were produced using the screencasting and editing software Camtasia. This software offers the ability to integrate quiz questions directly through its editing interface so that the videos can then be exported in a Shareable Content Object Reference Model (SCORM) format that can directly integrate with PowerSchool. In other words, the video with its embedded quiz questions could be uploaded to PowerSchool, and I could then see each student's progress in the video, how they had answered questions, and could even have a score placed directly and automatically into the gradebook without ever leaving the LMS. I found, however, that students could only answer the questions once, and after each video assignment had been completed, students could no longer see

the questions. Instead, the video would simply play straight through. Therefore, I opted to produce the videos in Camtasia, and used EdPuzzle to both host the videos and embed questions. Any questions I embedded in videos through EdPuzzle continued to be visible to students after they had completed the video assignment. Additionally, I could embed EdPuzzle videos directly into my pages on PowerSchool whereas videos in the SCORM format would appear as links on the pages that students had to then follow that would popup a separate window with awkward navigation controls and limited or no functionality on iOS devices. In considering the cognitive load put on students to merely access the video content (Mayer & Moreno, 2003), I found that EdPuzzle was the best method of delivery.

To gather data regarding students' perceptions of their engagement and collaboration, during both treatment and non-treatment units, students completed a survey to rate the clarity, usefulness, and level of interest in the unit's lessons and activities, and to rate their collaboration and effectiveness in their groups (Appendix B). These surveys were administered anonymously through Google Forms. Results were analyzed by grouping and comparing rating scale responses for each question on the surveys from the non-treatment and treatment units. These groupings were represented graphically to simplify analysis.

To measure content learning, students completed a quiz at the end of each subunit; two were completed in the non-treatment unit and two were completed in the treatment unit. Quiz items were formatted as multiple-choice and short answer questions. Students were allowed to retake quizzes for a total of two attempts after reviewing their

notes and any other instructional materials, including videos in the treatment unit. Final quiz scores were calculated as the mean of all attempts. Students also completed a summative assessment task at the end of each subunit as part of the Evaluate lesson in the 5E cycle that called on students to model through diagrams, drawings, and written explanations their understanding of concepts developed in the subunit. Students' work was assessed using the Modeling Rubric provided to them beforehand (Appendix C). Students completed two modeling assessments in the non-treatment unit, but due to unforeseen scheduling conflicts with end-of-year school activities, we only had time to complete one modeling assessment in the treatment unit. Quizzes and modeling assessments were analyzed by calculating the median, maximum and minimum values, and upper and lower quartiles of the scores from each assessment. Box plots of these results were constructed to aid analysis. These results were compared between non-treatment and treatment assessments. To gather additional qualitative data, six students were randomly selected to participate in a post-treatment interview (Appendix D). Randomization was accomplished through use of a random number generator that corresponded to sequential numbers assigned to students on a class roster.

DATA AND ANALYSIS

This study sought to understand how employing a flipped learning instructional format would affect student comprehension, collaboration, and engagement. Comprehension was primarily measured though subunit quizzes and modeling assessments. Collaboration and engagement were measured through unit surveys, interviews, and teacher observations.

There was not a strong relationship between the flipped learning treatment and students' comprehension as measured by subunit quizzes and modeling assessments. Quiz scores in the non-treatment unit were relatively consistent between the two quizzes, while quiz scores in the treatment unit suggested an upward trend (Figure 1). In Non-Treatment Quiz 1, the median score was 88% with scores ranging from 50% to 100%, a difference of 66 points, with one outlier at 44% (N=63). Fifty percent of students fell within 75% and 94%, a 19-point range. In Non-Treatment Quiz 2, the median score was 88% with scores ranging from 56% to 100%, a difference of 44 points, with outliers at 13% and 25%. Fifty percent of students fell within 70% and 94%, a 24-point range. The non-treatment quizzes garnered fairly similar results, though the second quiz had a slightly smaller overall range with a slightly wider distribution of scores in the middle 50%.

In Treatment Quiz 1, the median score was 75% with scores ranging from 31% to 100%, a difference of 69 points. Fifty percent of students fell within 63% and 88%, a 25-point range. In Treatment Quiz 2, the median score was 100%, with scores ranging from 56% to 100%, a difference of 44 points, with one outlier at 44%. Fifty percent of students fell within 78% and 100%, a 22-point range.

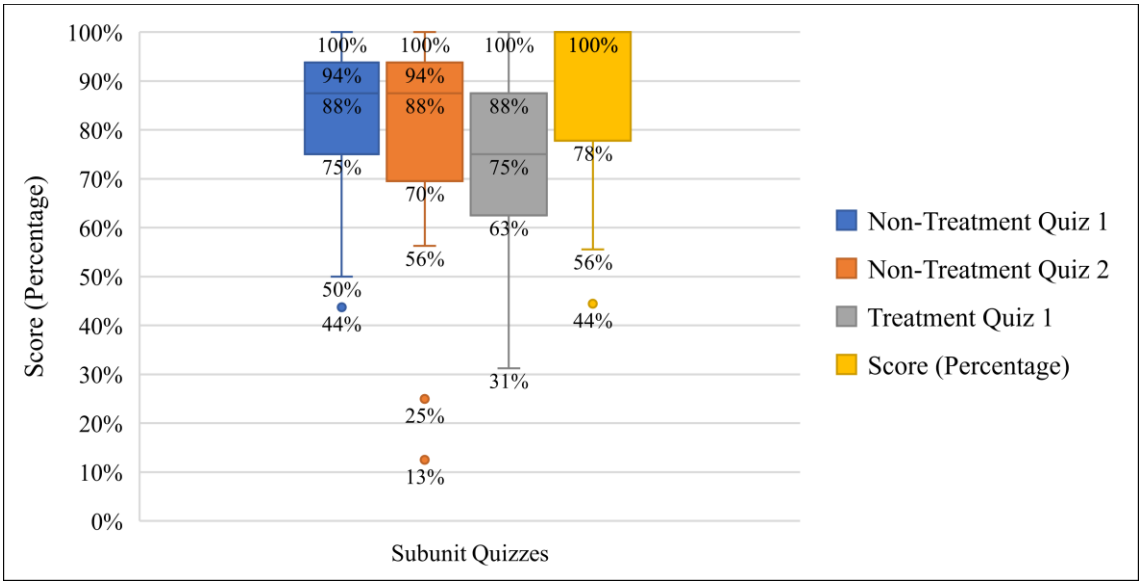


Figure 1. Middle school science subunit quiz scores at Synergy School, (*N*=63).

Similar scores on the modeling assessments were seen across non-treatment and treatment units (Figure 2). In Non-Treatment Modeling Assessment #1, the median score was 18, with scores ranging from 14 to 20, a difference of six points (*N*=63). Fifty percent of students' scores fell within 16 and 20 points, a difference of four points. In Non-Treatment Modeling Assessment #2, the median score was 19, with scores ranging from 14 to 20, a difference of six points. Fifty percent of students' scores fell within 17 and 20 points, a difference of three points. In Treatment Modeling Assessment #1, the median score was 18, with scores ranging from 14 to 20 points, a difference of six points. Fifty percent of students' scores fell within 16 and 20 points, a difference of four points.

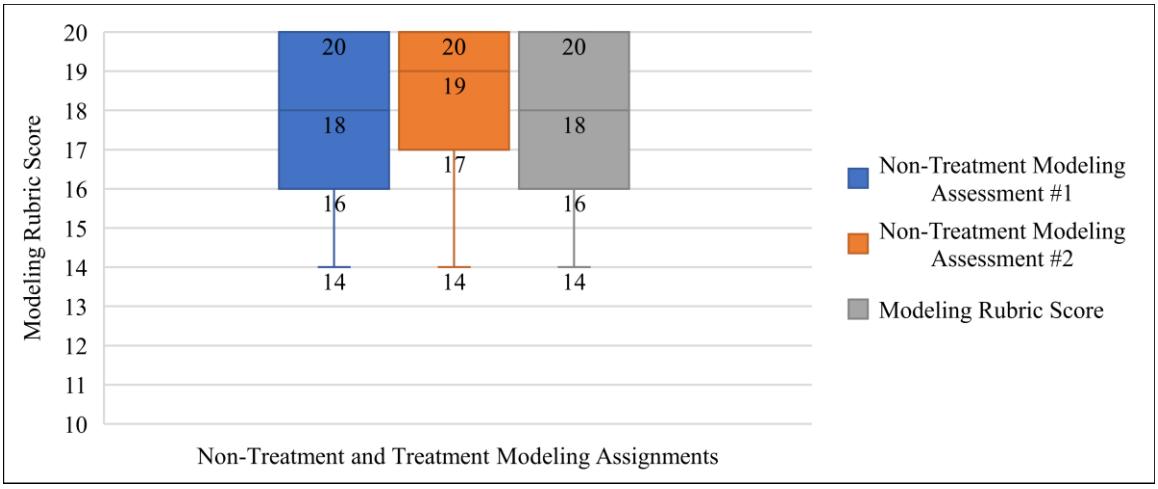


Figure 2. Middle school science modeling assessment scores at Synergy School, (*N*=63).

The treatment unit had mixed effects on students' self-perceptions of their collaboration in class. In the Unit Surveys, students were asked to estimate the frequency with which they followed or exhibited each group work behavior that had been identified earlier in the school year (Figure 3). For the behavior of "Everyone contributes," 93% of students said they "almost always" or "most of the time" exhibited the behavior during the non-treatment unit, but in the treatment unit, this number shifted to 85% (*N*=63). Seven percent more, however, said they exhibited the behavior "almost always" during the treatment unit, while three percent said they "almost never" exhibited the behavior; no students in the non-treatment unit responded "almost never" regarding this behavior. This corresponds with my in-class observations and discussions with students, as while I noticed many groups and individuals become more self-sufficient and accountable to each other in the treatment unit, I also noticed approximately three to five students in each class who experienced or reported greater difficulty engaging with their groups during in-class work time in the treatment unit. In the open-ended question on the treatment unit survey regarding group work, a common theme that came up was

inconsistent participation or contribution from group members: “Some of the group members in my group did their work and we worked together really well, but other people didn't do their work and didn't contribute their ideas or thoughts,” said one student. Two others noted a similar issue, but highlighted problems in group members’ physical proximity, writing that “a lot of my group would go away while we were working, but the people that I was working with worked well together,” and “One of our group members didn't sit with us all the time but besides him I would say our group worked well.”

For the behavior of “Rephrase and build on others’ ideas,” very little difference was seen between the two units, with 87% of students responding that they had exhibited the behavior almost always or most of the time in the non-treatment unit, while 86% of students indicated the behavior almost always or most of the time in the treatment unit. The same was mostly true of the behavior “Help others do things for themselves,” with 86% of students indicating the behavior almost always or most of the time in the non-treatment unit, and 84% of students indicating the behavior almost always or most of the time in the treatment unit.

A subtle difference between the two units emerged for the behavior of “Listen and pay attention to what is being said by others.” Ninety-three percent of students rated themselves as exhibiting the behavior “almost always” or “most of time” in the non-treatment unit, while that figure for the treatment unit was 97% of students. In the treatment unit, only three percent of students said they exhibited the behavior “some of the time,” and no students indicated “almost never” exhibiting the behavior.

Responses for the behavior of "Explain by telling how/why" were similar with 86% of students in the non-treatment unit indicating the behavior almost always or most of the time, while 88% of students in the treatment unit indicated the behavior almost always or most of the time.

For the behavior of "Play your role in the group," 90% of students in the non-treatment unit indicated exhibiting the behavior almost always or most of the time, with 68% of all students selecting "almost always," and no students selecting "almost never." In contrast, while 88% of students in the treatment unit indicated the behavior almost always or most of the time, only 61% of all students selected "almost always," and two percent of students selected "almost never." This behavior norm is about carrying out of the previously mentioned weekly assigned roles. In the treatment unit survey, one student expressed confusion about the very existence of assigned groups within the unit: "This Unit was a flipped learning unit and I was wondering why it would be group work throughout the unit." Another expressed a similar idea, writing, "Note that our group divided. We never worked together but we often worked in partners." In my observations during the treatment unit, I noticed that students began to group themselves more organically and move to different parts of the room throughout the lengthier work time. Additionally, I was less inclined to enforce, as it were, the assigned groups during the treatment unit so long as I saw that students were on-task.

For the behavior of "Pay attention to what other group members need," 91% of students in the non-treatment unit indicated the behavior almost always or most of the time, while 97% of students in the treatment unit indicated the behavior almost always or

most of the time. This difference seems to suggest that while some students expressed frustration with group members not contributing or that they had rearranged themselves into groupings different from what had been assigned, nonetheless, they found themselves paying more attention to the needs of their peers in the treatment unit.

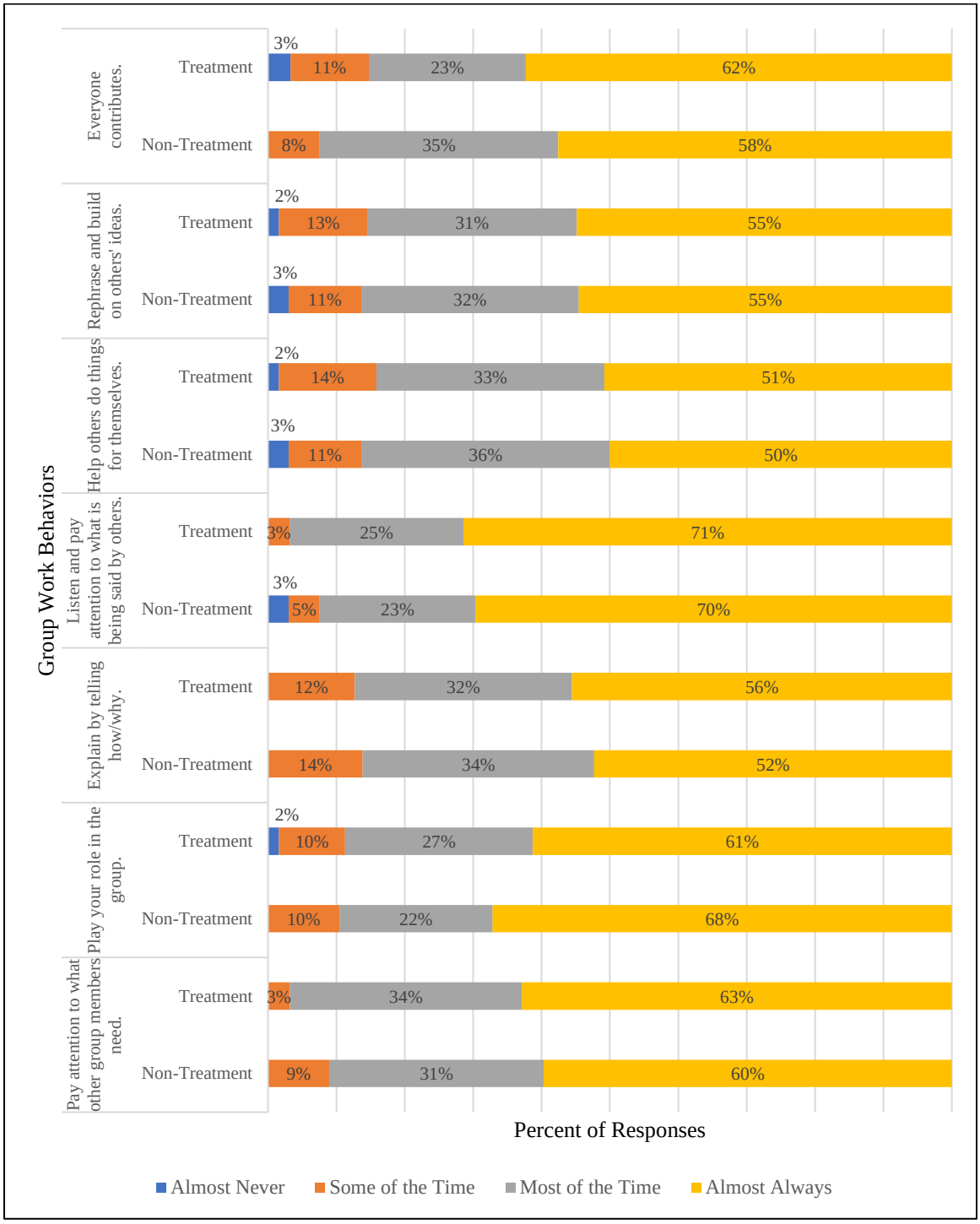


Figure 3. Unit Survey responses regarding group work behaviors, (*N*=63).

When asked to rate how well their assigned groups worked together during each unit, 30% of students in both the non-treatment and treatment units said their groups

worked “extremely well.” In the non-treatment unit, 52% of students said their groups worked “well,” and 18% of students said their groups worked “adequately.” In the treatment unit, 59% of students said their groups worked “well, five percent of students said their groups worked “adequately,” and six percent of students said their groups worked “poorly” (Figure 4). While 7% more students in the treatment unit gave their groups favorable ratings of “well” or “extremely well,” the six percent who rated their groups’ work as “poor” stands in contrast to no students in the non-treatment unit rating their groups’ work as “poor.” This suggest a slight polarization of students’ perceptions about group work in the treatment unit relative to the non-treatment unit that corresponds with the previously mentioned feedback from students that while a some group members were perceived by others to be contributing less or were less present, many students felt that whatever groups did form were relatively effective.

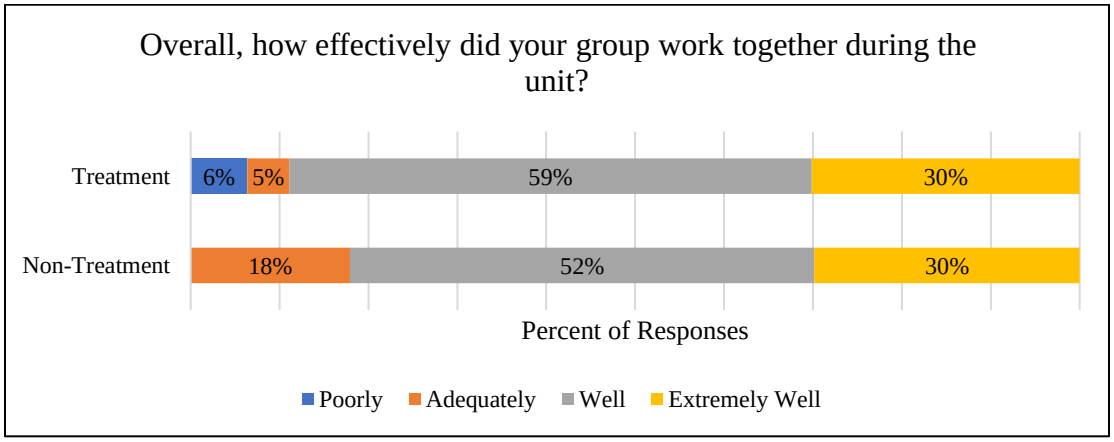


Figure 4. Students' ratings of group effectiveness from Unit Surveys, (*N*=63).

In their interview, one student noted that across the two units, “I didn’t really experience very much group work because my table was not very useful at all. Depending on which students you have and how well they work together, the group either works or doesn’t work.” The student explained as well that how well they perceived getting along with

another student impacted greatly their willingness to engage with those students in assigned group settings.

In the Unit Surveys, students were also asked to rate their own engagement in the unit by considering their perceptions of the clarity, interest, and usefulness of the lessons in the unit covered by the survey. These questions revealed that while students had similar interest in the non-treatment and treatment unit lessons, there was some polarization of opinion regarding lesson clarity and usefulness.

In rating the clarity of the non-treatment lessons, 34% of students rated the lessons as “very clear,” 56% rated the lessons as “mostly clear,” 10% rated the lessons as “somewhat unclear,” and no students rated the lessons as “totally unclear” (Figure 5). In the survey of the treatment unit, there was a slight move to the extremes with 39% of students rating the lessons as “very clear,” an increase of five percent over the non-treatment unit, and two percent of students rated the lessons of the treatment unit as “totally unclear.” The rating of lessons as “mostly clear” was similar at 54% of students, while the rating of “somewhat unclear” dropped to five percent of students. One student noted in their survey response that “getting the videos down at first weren't the easiest which kind of skewed my understanding of some of the material for a short period.”

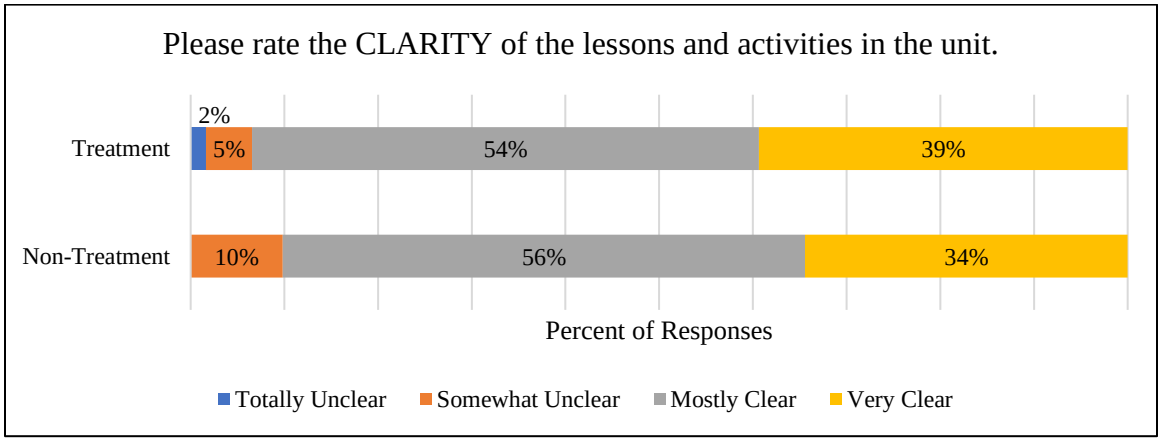


Figure 5. Students' ratings of lesson clarity through Unit Surveys, (*N*=63).

Students' rating of interest in the lessons was relatively consistent between the non-treatment and treatment units (Figure 6). In the non-treatment unit, 80% of students found the lessons to be "very interesting" or "somewhat interesting," while in the treatment unit 79% of students reported the same ratings. In the non-treatment unit, 20% of students found the lessons to be "mostly boring" or "totally boring," while in the treatment unit 21% of students reported these ratings. Distribution among the ratings was similar between the non-treatment and treatment units.

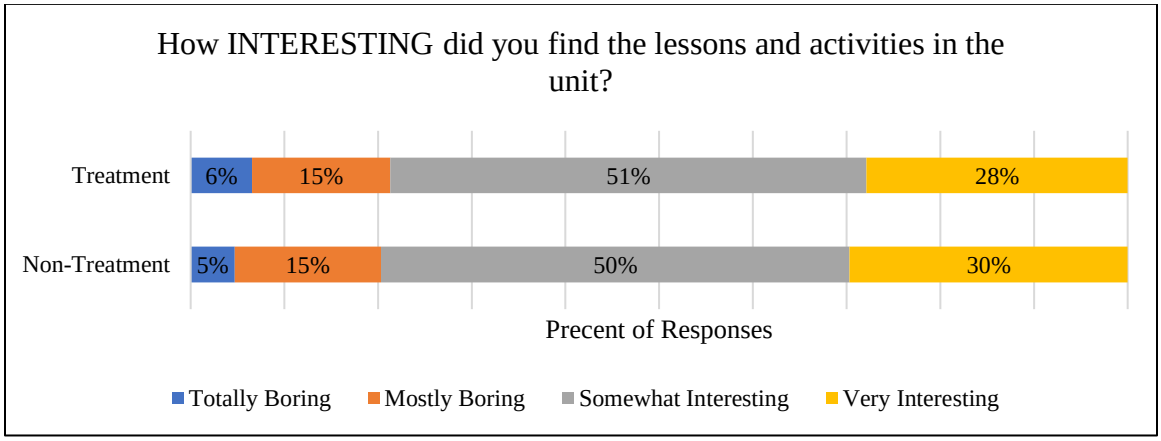


Figure 6. Students' ratings of lesson interest through Unit Surveys, (*N*=63).

In rating the usefulness of the lessons, there was again a similar distribution between the non-treatment and treatment units (Figure 7), though with the notable

difference that while no students in the non-treatment unit had rated the lessons as "useless," five percent of students in the treatment unit gave this rating. Nonetheless, most students found the lessons useful with 94% of students rating them "very useful" or "somewhat useful" in the non-treatment unit, and 90% of students in the treatment unit giving the same ratings.

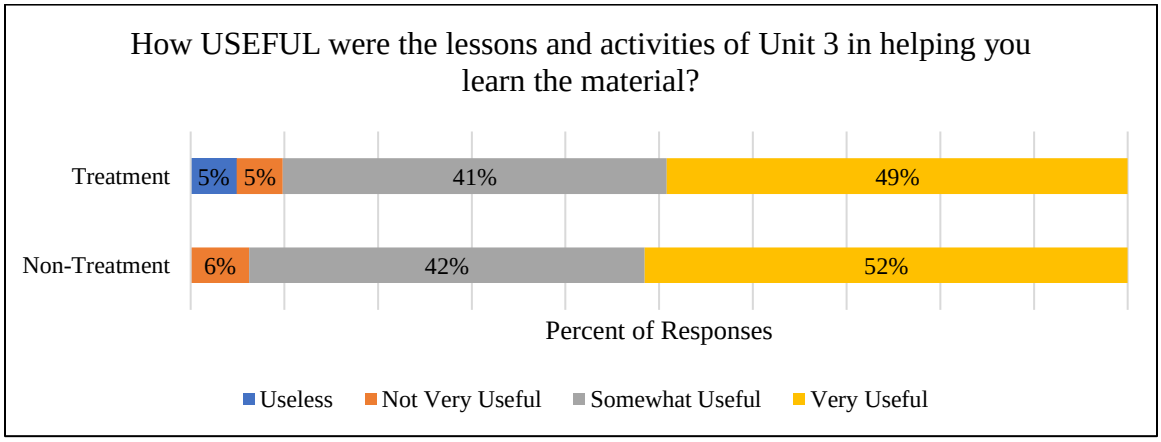


Figure 7. Students' ratings of lesson usefulness through Unit Surveys, (*N*=63).

Two students noted in their survey responses that they found the assigned work in the treatment unit to be repetitive, one writing that "I know this was your first year, Jeff, so no worries but some of the lessons and questions asked were kind of repetitive. Not all of them but I felt sometimes like I was just answering the same questions over and over." The other student got more specific:

> At the start of the year, I felt really good about Science Class and had very much fun during it. As the year went on, Jeff introduced "Student Books," and after that, everything went down for Science Class. I felt that every class would get more and more repetitive, as questions would be repeated over and over again and lessons would get less and less interesting.

The student books that this student refers to are part of the SFUSD/SCALE curriculum I selected in part to keep materials and unit structure consistent between the non-treatment and treatment units. This introduces the possibility that students' reported perceptions of

lesson clarity, interest, and usefulness may be connected to lesson materials in addition to instructional methods. This therefore makes it more difficult to draw conclusions based on the available data about the effect of flipped learning on students' engagement.

Overall, there was not a strong relationship between the flipped learning treatment and comprehension, though quiz scores suggest an upward trend that would need more data points to verify. The effect on student collaboration was mixed, with some students perceiving that their group mates were disengaging and some reporting that they were disengaging while there was also a slight increase in students reporting group engagement and collaboration behaviors "almost always." The effect on student engagement with lessons and content remained steady in terms of interest, but polarized slightly in perceived clarity and usefulness.

INTERPRETATION AND CONCLUSIONS

While there is not a clear indication that the flipped learning treatment unit improved student comprehension, there is likewise not a clear indication that comprehension was diminished. Student performance on modeling assessments was remarkably similar across non-treatment and treatment units. The exact same distribution was seen between the first non-treatment modeling assessment and the first treatment modeling assessment with median scores of 18 points, 50% of students scoring between 16 and points, and the total range of scores spread over 14 to 20 points. It should be noted that 14 points is the lower threshold of the Modeling Rubric, while 20 points is the maximum score. The second modeling assessment in the non-treatment only had a slightly tighter spread of scores with 50% of students scoring between 17 and 20 points,

and a median score of 19 points. The minimum score was again 14 points. Scores of 18 and above represent proficiency. Modeling was a science and engineering practice students had been using in the semester prior to the units included in this study, so the skill was likely already established. Flipped learning techniques did not seem to affect students' ability to express understanding through modeling, yet students were still able to proficiently model accurate concepts across the non-treatment and treatment units. This suggests that students had adequate opportunity to engage with content in both units within the context of modeling practices. This may suggest that the active learning components of both units enabled the self-learning to "solve problems independently and collaboratively" that Lim and Wilson (2018) describe.

Quiz scores seem to tell a slightly more dynamic story. While scores on the two non-treatment quizzes showed a similar distribution with median scores of 88%, the first treatment quiz showed a notable dip in comparison with a median score of 75%, followed by remarkably high scores on the second treatment quiz with a median score of 100%. I wonder if the scores on the first treatment quiz might represent an implementation dip (Fullan, 2001) wherein students were adapting to instructional techniques they were not familiar with or had not previously experienced. While both units incorporated a fair amount of student-driven cooperative learning, the non-treatment unit utilized traditional delivery methods during class as well such as guided discussions and lectures, readings, and the like, particularly at the explain phase in the 5E cycle. Students often mentioned that these lessons were the most critical to their success on quizzes as these lessons contained much of the vocabulary and explanations of concepts that the quizzes later

assessed. Under the flipped learning model as it was implemented in the treatment unit, though, more responsibility was put on students to actively and even individually pursue this type of content. In other words, they could not simply wait for class to happen to them, trusting that anything that might show up on a quiz would have been "gone over" in class by the teacher. Rather, students would need to go over the video content on their own, perhaps more than once. This seemed to empower many students while seemingly leaving behind a few. Some students expressed to me in class during the treatment unit that they felt genuinely lost. Furthermore, one student noted in their interview that in the first half of the treatment unit, they had gotten behind in their work and had actually missed some of the lessons that featured videos, that this had caused some confusion for them, and that at the time of the interview had still not yet watched those videos. When I asked this student about their thoughts about having class resources like the videos posted online for students to access at any time, they responded thus:

> It's cool, especially since with the normal units you put all the slideshows in PowerSchool, it makes it really easy to go over—if you have your notebook with you—to just go over and do the unit at home, especially since with the flipped learning you're doing less teaching and class, and more like… homework teaching. That's helpful, especially for me since I've gotten sick a lot, especially last year, this year it's been a lot easier because all the work is on PowerSchool.

Another student interviewed mentioned not being entirely aware of the existence of the videos in first part of the treatment unit, but explained that once they began watching the videos, they found them useful, particularly in being able to pause them and re-watch sections as needed. This underscores the recommendation by Bergman and Sams (2015) that videos should be easy for students to access. All this said, the second treatment quiz yielded very high scores that, while showing a distribution similar to the other quizzes,

had a median of 100%. While I would want to see more data points in order to truly establish an upward trend, this is nonetheless encouraging and does not seem to be contrary to the findings of Day and Foley (2006) or Moravec et al. (2010).

What was particularly striking to me was how collaboration and group work transformed during the treatment unit. As previously discussed, students were more apt to regroup themselves during the treatment unit, with 4% more students reporting that everyone contributed in their group "almost always," and 6% more students reporting everyone contributed only "some of the time" or "almost never." While this may have been partly a function of the unit taking place during the final quarter of the year, I think that this was also due to the large chunks of time that students had to work with during class, and that within these wide boundaries, students self-selected into groups that worked well for them. This could mean working with partners who work at similar speeds, with whom they have existing positive relationships, with those who share preferences for group size such as relatively large or small or even individual, and with those who are working on the same assignments. This last piece emerged as a pleasant surprise. I have often struggled with assigned mixed-ability groups to keep everyone moving and engaged, particularly if some members of the group are behind or ahead of other members. With the structure of class time shifted to almost entirely student work time, having everyone in the same place started to matter less, and I became more comfortable letting students be where they needed to be, and working on what they needed to work on, even if that meant they were not "on schedule."

As indicated by the survey results, this arrangement worked for many, but not for some. For some students who were already struggling, the flipped environment as it was implemented here may have proved to be a bit too unstructured. In the non-treatment unit (and in units earlier in the year), it was evident that some struggling students were supported and scaffolded by peers in their assigned groups, which after all was by design. When these groups became more fluid, however, some struggling students lost their in-class support systems, particularly those who were less likely to engage with their groups. I noticed this and it also came up in the surveys when students noted their perceptions either that some group members were not contributing or were not present. Students also reported playing their role in their groups less often, with 6% fewer students in the treatment unit reporting this behavior "almost always" and two percent reporting the behavior "almost never," a response that no students gave in the non-treatment unit. I suspect that this is because some of the built-in collaboration structures such as designated group roles dissolved a bit in the treatment unit, and this was hard for students who need that structure. I further think that this highlights the importance of the recommendation by Winter (2018) that effective differentiation strategies are necessary to support a flipped learning environment. While I was certainly able to fit in quite a few more one-on-one conversations with students and quickly clear up many more misconceptions during the treatment unit as Bergman and Sams (2015) noted they were able to, some students still fell through the cracks and in some ways fell farther through the cracks.

Based on students' feedback through surveys and interviews, and in my own observations, there was little change in students' engagement. The surveys showed that students found the two units similarly interesting with 80% of students in the non-treatment unit reporting the lessons and activities as "somewhat interesting" or "very interesting," while in the treatment unit that number was 89%. Some students, though, volunteered in their surveys that the assignments themselves were a bit boring and redundant. Nonetheless, for both non-treatment and treatment units, students noted in interviews that the units were "in-depth," which one student mentioned was a notable difference from their previous science class experiences. When I started this project, I observed that, for the most part, my students were already highly engaged. If I am looking to further enhance engagement, I may need to look into techniques beyond simply rearranging how class time is used.

While the survey showed a slight diminishment of students' perceived usefulness of the lessons in the treatment unit with five percent of students rating them as "useless" while no students gave that rating in the non-treatment unit, several students I interviewed mentioned that having the videos available was particularly useful if they had been absent or for purposes of reviewing content. This application connects back to the original reason Bergman and Sams (2015) began recording videos for their classes in the first place, which was to provide content for students who had been absent from lectures. I also wonder how students perceived the question of usefulness of lessons. As mentioned previously, several students mentioned in surveys, interviews, and classroom conversations that they were finding the activities they were working through in class,

and particularly the analysis questions attached to them, to be redundant. I can imagine that this could translate to a perception of these lessons as less useful. It is possible that the videos were not considered by students as lessons when answering this particular survey item. Further investigation may help to determine this.

In terms of my relationships with students, I found that during the treatment unit, I was able to engage in conversations with students with less of my usual anxiety of needing to make it quick so I could move on to the next student or group before class time ran out. I knew I had more time to work with, so I could actually spend time with groups and individuals to more comprehensively probe their thinking as well as simply get to know them better as people. I also had more time to simply observe; I could see better how individual students worked, who best they worked with, and, in the role of professional educator articulated in the Flipped Learning Network's (2014) fourth pillar of the professional educator, I could make more informed decisions about when I needed to step in and when to step back.

While there was no major change in comprehension, employing flipped learning techniques in my classroom saw my students continue to do well on open-ended modeling assessments and showed the possibility of increased performance on quizzes. Collaboration became more organic within the expanded class-time context with students moving through various groupings according to their needs and learning styles, though some struggled in this less structured environment. While student engagement saw little change, I did find that I was able to engage more often and more comprehensively with individual students under the flipped learning model.

VALUE

My most significant takeaway from this project was realizing the ideal classroom I want for my students is one that is centered around active student learning, and that is student-driven. That is, the class prioritizes their active time, differentiates the ways in which they may work, and provides them a variety of activities and resources to support their learning, including but not limited to the types of videos I developed for this study. I saw that a flipped model can empower students. One student interviewed said that they "liked the independence. It was like you got to do stuff by yourself, or with a partner, but you got to teach yourself with all the different activities… I like it because I can go at my own pace." What flipping my classroom really did was to open up the in-class space for rich experiences for which I must now develop more robust systems of support. I am not confident that the in-class supports were as developed or intentional as I would want them to be during this study; rather, my focus was truly on developing the out-of-class materials (namely, videos) and simply making myself available during class as students worked through their assignments. Seeing them work more naturally and organically was exciting, but I want to provide more clear paths and options to students so that those who are more likely to get lost without a great deal of guidance will have a better idea of where they are going, and those who move quickly through their work will have options they can choose for themselves without waiting for me.

The SFUSD/SCALE curriculum I worked from is built on the assumption that students are working in four-person groups with assigned roles at all times. It is clear from my students that while they do enjoy and see legitimate value in working in groups,

and even in having a group available to consult with as needed, they do not enjoy and even find frustrating being assigned to work in groups at all times. As I am planning my next year of instruction, I am considering ways to make groupings more flexible with students assigned to "home groups" of four for several key assignments, while they can branch out to a menu of individual and partner tasks for their other work. While I intend to further develop my understanding and implementation of collaborative learning, it is clear to me from this study that flexibility is critical. One student told me in their interview that "group work was challenging for me because I like to work individually a lot. It would be nice to have that as an option… It was a little bit frustrating for me when my group wouldn't really be helping out at all." Another mentioned that "it kind of gets boring when you're just with the same person the whole time. Maybe more frequent new seating arrangements." While intentional collaboration is a piece of the class I want to maintain, I will need to find ways to differentiate it.

While I have long prided myself on being a flexible teacher with good relationships with my students, I saw that by spending as much time as possible away from the front of the room and immersed in the work alongside students truly helped me to know them better and to understand that there is always more space in and more approaches to learning than I believe there to be. Not only do I now know better how specific students learn, where their strengths and struggles are, but I also know them better as people. I know their humor, things about their families and friends, their anxieties, and their dreams. I want to continue to find ways in which I can make the class

more flexible, the actual doing of science more flexible, and how I can support students through these processes.

It is this doing of science, rather than just learning about science, that students showed in the project they are most capable of and most want to do. I saw this in their modeling assessments and, though it was not included as an instrument in this project, in their science notebook work. As I think about how to make the most of in-class time, I need to ensure that this orientation of doing rather than just learning about guides my decisions, and that I continually monitor and check in with students around this.

Moving forward, it is clear to me that I want to continue to incorporate pieces of a flipped learning model into my teaching. I want to prioritize in-class time for active student learning and collaboration, and I want to build a library of resources available online for students to access from anywhere at any time. Interactive videos will be a piece of this, but there may be more out there for me to investigate. As I saw in this study, though, students may not always be motivated to access these resources independently, or they may have challenges in being aware of the resources or knowing how to use them. I will therefore need to find ways to orient students to the resources, teach them how to access and use them, and develop systems of accountability. With these measures in place, I believe I will be able to move my classroom even closer to the Synergy School mission "to nurture the intellectual, creative, and emotional potential of every child."

REFERENCES CITED

Anderson, L. W., Bloom, B. S., & Krathwohl, D. R. (2001). *A taxonomy for learning, teaching, and assessing : a revision of Bloom's taxonomy of educational objectives* (Complete ed.. ed.). New York: Longman.

Ash, K. (2012). Educators evaluate flipped classrooms. *Education Week, 32*(2), s6-s8.

Barrows, H. S. (1996). Problem-based learning in medicine and beyond: A brief overview. *New Directions for Teaching and Learning, 1996*(68), 3-12. doi:10.1002/tl.37219966804

Bergman, J., & Sams, A. (2015). *Flipped learning for science instruction*. Eugene, OR: International Society for Technology in Education.

Bishop, J., & Verleger, M. A. (2013). *The Flipped Classroom: A Survey of the Research*. Atlanta, Georgia. https://peer.asee.org/22585

Bloom, B. S. (1956). Taxonomy of educational objectives. Vol. 1: Cognitive domain. *New York: McKay*, 20-24.

Chase, W. G., & Simon, H. A. (1973). Perception in chess. *Cognitive Psychology, 4*(1), 55-81. doi:https://doi.org/10.1016/0010-0285(73)90004-2

Day, J. A., & Foley, J. D. (2006). Evaluating a Web Lecture Intervention in a Human-Computer Interaction Course. *IEEE Transactions on Education, 49*(4), 420-431. doi:10.1109/te.2006.879792

de Grazia, J., L. , Falconer, J., L. , Nicodemus, G., & Medlin, W. (2012). *Incorporating ScreenCasts into Chemical Engineering Courses*. San Antonio, Texas. https://peer.asee.org/21519

Ehly, S. W., & Topping, K. J. (1998). *Peer-assisted learning*. Mahwah, N.J.: L. Erlbaum Associates.

The Four Pillars of F-L-I-P™. (2014). Retrieved from http://www.flippedlearning.org/definition

Fullan, M. (2001). *Leading in a culture of change*: John Wiley & Sons.

Hmelo-Silver, C. E. (2004). Problem-Based Learning: What and How Do Students Learn? *Educational Psychology Review, 16*(3), 235-266. doi:10.1023/B:EDPR.0000034022.16470.f3

Johnson, D. W. (1984). *Circles of learning : cooperation in the classroom*. Alexandria, Va.: Association for Supervision and Curriculum Development.

Kolb, D. A. (1984). *Experiential learning : experience as the source of learning and development*. Englewood Cliffs, N.J.: Prentice-Hall.

Lim, K. H., & Wilson, A. D. (2018). Flipped Learning: Embedding Questions in Videos. *Mathematics Teaching in the Middle School, 23*(7), 378-385.

Mayer, R. E., & Moreno, R. (2003). Nine Ways to Reduce Cognitive Load in Multimedia Learning. *Educational Psychologist, 38*(1), 43-52.

Michael, J. (2007). *Where's the evidence that active learning works?* (Vol. 30).

Moravec, M., Williams, A., Aguilar-Roca, N., & O'Dowd, D. K. (2010). Learn before lecture: A strategy that improves learning outcomes in a large introductory biology class. *CBE Life Sci Educ, 9*(4), 473-481. doi:10.1187/cbe.10-04-0063

Piaget, J. (1967). *Six psychological studies*. New York: Random House.

Prince, M. (2004). Does Active Learning Work? A Review of the Research. *Journal of Engineering Education, 93*(3), 223-231. doi:10.1002/j.2168-9830.2004.tb00809.x

Progressive Education. (2019). *Synergy School.* Retrieved from https://www.synergyschool.org/progressive-education

Rottier, J. (1991). *Cooperative learning in middle-level schools*. Washington, D.C.: NEA Professional Library, National Education Association.

Sharan, S. (1990). *Cooperative learning : theory and research*. New York: Praeger.

Slavin, R. E. (1991). Synthesis of research on cooperative learning. *Educational Leadership, 48*(5), 71.

Slemmons, K., Anyanwu, K., Hames, J., Grabski, D., Mlsna, J., Simkins, E., & Cook, P. (2018). The Impact of Video Length on Learning in a Middle-Level Flipped Science Setting: Implications for Diversity Inclusion. *Journal of Science Education and Technology, 27*(5), 469-479. doi:10.1007/s10956-018-9736-2

Smith, B. L., & MacGregor, J. (1992). What is collaborative learning? In M. Maher, A. M. Goodsell, & V. Tinto (Eds.), *Collaborative learning: A sourcebook for higher education* (pp. 10-30): National Center on Postsecondary Teaching, Learning and Assessment.

Tomlinson, C. A. (1999). *The Differentiated Classroom: Responding to the Needs of All Learners*: Association for Supervision and Curriculum Development.

Tomlinson, C. A. (2001). *How to Differentiate Instruction in Mixed-ability Classrooms*: Association for Supervision and Curriculum Development.

Tomlinson, C. A., & Moon, T. R. (2013). *Assessment and Student Success in a Differentiated Classroom*: Association for Supervision & Curriculum Development.

Toto, R., & Nguyen, H. (2009). *Flipping the work design in an industrial engineering course*. Paper presented at the Proceedings of the 39th IEEE international conference on Frontiers in education conference, San Antonio, Texas, USA.

Tucker, B. (2012). The flipped classroom: online instruction at home frees class time for learning. *Education Next, 12*, 82+.

Vygotsky, L. S. (1978). *Mind in society : the development of higher psychological processes*. Cambridge: Harvard University Press.

Winter, J. W. (2018). Performance and Motivation in a Middle School Flipped Learning Course. *TechTrends, 62*(2), 176-183. doi:10.1007/s11528-017-0228-7

Wormeli, R. (2018). *Fair Isn't Always Equal: Assessment and Grading in the Differentiated Classroom*: Stenhouse Publishers.

Zappe, S., Leicht, R., Messner, J., Litzginer, T., & Lee, H. W. (2009). *"Flipping" the classroom to explore active learning in a large undergraduate course*.

APPENDICES

APPENDIX A

INSTITUTIONAL REVIEW BOARD EXEMPTION

MONTANA STATE UNIVERSITY

INSTITUTIONAL REVIEW BOARD

For the Protection of Human Subjects
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MEMORANDUM

TO: Jeffrey McMahan and Marcie Reuer

FROM: Mark Quinn Mark Quinn CHJ
Chair, Institutional Review Board for the Protection of Human Subjects

DATE: March 18, 2019

RE: *"Flipped Learning in Middle School Science" [JM031819-EX]*

The above research, described in your submission of March 12, 2019, is exempt from the requirement of review by the Institutional Review Board in accordance with the Code of Federal regulations, Part 46, section 101. The specific paragraph which applies to your research is:

X	(b) (1)	Research conducted in established or commonly accepted educational settings, involving normal educational practices such as (i) research on regular and special education instructional strategies, or (ii) research on the effectiveness of or the comparison among instructional techniques, curricula, or classroom management methods.
X	(b) (2)	Research involving the use of educational tests (cognitive, diagnostic, aptitude, achievement), survey procedures, interview procedures or observation of public behavior, unless: (i) information obtained is recorded in such a manner that human subjects can be identified, directly or through identifiers linked to the subjects; and (ii) any disclosure of the human subjects' responses outside the research could reasonably place the subjects at risk of criminal or civil liability, or be damaging to the subjects' financial standing, employability, or reputation.
____	(b) (3)	Research involving the use of educational tests (cognitive, diagnostic, aptitude, achievement), survey procedures, interview procedures, or observation of public behavior that is not exempt under paragraph (b)(2) of this section, if: (i) the human subjects are elected or appointed public officials or candidates for public office; or (ii) federal statute(s) without exception that the confidentiality of the personally identifiable information will be maintained throughout the research and thereafter.
____	(b) (4)	Research involving the collection or study of existing data, documents, records, pathological specimens, or diagnostic specimens, if these sources are publicly available, or if the information is recorded by the investigator in such a manner that the subjects cannot be identified, directly or through identifiers linked to the subjects.
____	(b) (5)	Research and demonstration projects, which are conducted by or subject to the approval of department or agency heads, and which are designed to study, evaluate, or otherwise examine: (i) public benefit or service programs; (ii) procedures for obtaining benefits or services under those programs; (iii) possible changes in or alternatives to those programs or procedures; or (iv) possible changes in methods or levels of payment for benefits or services under those programs.
____	(b) (6)	Taste and food quality evaluation and consumer acceptance studies, (i) if wholesome foods without additives are consumed, or (ii) if a food is consumed that contains a food ingredient at or below the level and for a use found to be safe, or agricultural chemical or environmental contaminant at or below the level found to be safe, by the FDA, or approved by the EPA, or the Food Safety and Inspection Service of the USDA.

Although review by the Institutional Review Board is not required for the above research, the Committee will be glad to review it. If you wish a review and committee approval, please submit 3 copies of the usual application form and it will be processed by expedited review.

APPENDIX B

UNIT SURVEY

Unit 4 Research Survey

Participation in this research is voluntary and participation or non-participation will not affect a student's grades or class standing in any way.

* Required

1. **Select your grade.** *
   Mark only one oval.
   - ◯ 6
   - ◯ 7
   - ◯ 8

2. **Select your block.** *
   Mark only one oval.
   - ◯ Block 1
   - ◯ Block 2
   - ◯ Block 3

Group-Work Evaluation

Participation in this research is voluntary and participation or non-participation will not affect a student's grades or class standing in any way.

3. **Rate how often you exhibited the following groupwork behavior norms throughout the WHOLE UNIT.**
   Mark only one oval per row.

	Almost Never	Some of the Time	Most of the Time	Almost Always
Pay attention to what other group members need.	◯	◯	◯	◯
Play your role in the group.	◯	◯	◯	◯
Explain by telling how/why.	◯	◯	◯	◯
Listen and pay attention to what is being said by others.	◯	◯	◯	◯
Help others do things for themselves.	◯	◯	◯	◯
Rephrase and build on others' ideas.	◯	◯	◯	◯
Everyone contributes.	◯	◯	◯	◯

5. **Any other comments or questions about groupwork during Unit 4?**

Lesson Evaluation

Participation in this research is voluntary and participation or non-participation will not affect a student's grades or class standing in any way.

When answering the following questions, think about the work you did for Science this week both in class and outside of class (i.e., for homework).

6. **Please rate the CLARITY of the lessons and activities in Unit 4.**
   Mark only one oval.
   - ◯ totally unclear
   - ◯ somewhat unclear
   - ◯ mostly clear
   - ◯ very clear

7. **How INTERESTING did you find the lessons and activities in Unit 4?**
   Mark only one oval.
   - ◯ totally boring
   - ◯ mostly boring
   - ◯ somewhat interesting
   - ◯ very interesting

8. **How USEFUL were the lessons and activities of Unit 4 in helping you learn the material?**
   Mark only one oval.
   - ◯ useless
   - ◯ not very useful
   - ◯ somewhat useful
   - ◯ very useful

9. **Any other comments or questions about the lessons and activities in Unit 4?**

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APPENDIX C

MODELING RUBRIC

Name: _____
Block: _____
Grade: _____

Modeling Rubric

	EMERGING	APPROACHES EXPECTATIONS	MEETS EXPECTATIONS	ADVANCED
SCORING ELEMENTS	7	8	9	10
CORE IDEAS	Identifies or otherwise applies **irrelevant** content OR relevant content with **major** errors or omissions.	Identifies or otherwise applies **relevant** content with **minor** errors or omissions.	Explains **or** otherwise applies **relevant** and **accurate** content.	Explains **and** applies **relevant** and **accurate** content.
DEVELOPMENT OF MODEL	Constructs models (e.g., 3D objects, drawings, or diagrams) relevant to the investigation with **major** conceptual or factual errors or omissions	Constructs models (e.g., 3D objects, drawings, or diagrams) to represent the process or system being investigated, with **minor** errors or omissions.	Constructs **accurate** and **labelled** models (e.g., 3D objects, drawings, or diagrams) to represent the process or system being investigated.	Constructs **accurate**, **labelled**, and **detailed** models (e.g., 3D objects, drawings, or diagrams) to represent the process or system being investigated and provides an **explanation** of the representation.
TOTAL: _____ / 20	**Notes:**			

Adapted from Literacy Design Collaborative, https://coretools.ldc.org/resources?expanded=c0f0c397-6c84-4b44-8027-a99bab742745

APPENDIX D

INTERVIEW QUESTIONS

Flipped Learning Interview Questions

Content

1. Tell me about what you learned in this unit. You may use your science notebook to help you explain. If you're looking for a place to start, start with the unit essential question. (post-unit)
2. What concepts made a lot of sense to you? Tell me more about them. (post-unit)
3. What concepts did you find challenging? Why might that be? (post-unit)

Engagement

1. What do you like about school? About science class? (pre-unit)
2. What kinds of activities in school do you find interesting? Fun? (pre-unit)
3. What kind of activities in school do you find most useful for you? (pre-unit)
4. What did you like about this unit? (post-unit)
5. What did you think was fun in this unit? (post-unit)
6. What did you think was interesting in this unit? (post-unit)
7. What did you think was useful in this unit? (post-unit)
8. What activities did you think helped you to be successful? Why? (post-unit)
9. What activities did you find challenging? Why? (post-unit)
10. If we were to continue learning about this topic, what would you want to do next? (post-unit)

Collaboration

1. What did you find helpful or useful about groupwork in this unit? (post-unit)
2. What did you find challenging about groupwork? (post-unit)
3. Describe one time your group worked together well. (post-unit)