FLIPPED INSTRUCTION IN ALGEBRA 1: IS IT AN OLD IDEA IN NEW CLOTHES?

Wenmin Zhao
University of Missouri
wenminzhao@mail.missouri.edu

Jessica Kamuru
University of Missouri
jgc7vc@mail.missouri.edu

Samuel Otten
University of Missouri
ottensa@missouri.edu

Zandra de Araujo
University of Missouri
dearaujoz@missouri.edu

What are the substantive differences between flipped and non-flipped instruction? This study examined the instruction of two teachers who have worked together within the same school using the same Algebra 1 curriculum for years. One teacher flipped his instruction (creating lecture videos assigned as homework), while the other teacher continued with non-flipped instruction. Data from classroom observations were analyzed qualitatively using the Flipped Mathematics Instruction Framework. Results show that although there were clear differences in the format of flipped and non-flipped lessons, there were also substantial similarities with regard to features of instruction (e.g., procedural mathematical development, teacher authority, and tasks with low cognitive demand). Our analysis indicates that flipped instruction is not necessarily an innovative model when compared with non-flipped.

Keywords: Flipped instruction, Instructional activities and practices, Algebra, Technology

Introduction

In the past decade, mathematics teachers have increasingly adopted or at least tried flipped instruction in their classrooms (Smith, 2014). *Flipped instruction* is an instructional model in which a teacher assigns videos or other types of multimedia to be viewed as homework, which frees up in-class time for other purposes such as practice problems or collaboration (Bergmann & Sams, 2012). With the increased availability of electronic devices accessible to students, flipped instruction holds promise in terms of allowing students access to lectures at their own pace (and also retroactive access), as well as allowing the teacher to use more of the classroom time for activities that are more collaborative than lecture-based.

Flipped instruction is often regarded as innovative due to the use of video technology or the fact that it appears on the surface to be different than the traditional lecture model of mathematics teaching. Some advocates of flipped instruction (e.g., Bergmann & Sams, 2012) believe that its innovative nature may lead to more favorable student outcomes. However, it is still unknown whether flipped instruction as implemented by secondary mathematics teachers is substantively different than non-flipped instruction. Therefore, in this study, we examined the similarities and differences between the instruction of two teachers, one employing flipped instruction and the other not, who are from the same mathematics team within the same school using the same curriculum for lessons on Exponential Rules. More specifically, in this paper we use the Flipped Mathematics Instruction Framework (Otten, de Araujo, & Sherman, 2018) to answer the following research question:

In what ways are these flipped and non-flipped lesson implementations similar and different with regard to activity formats, duration, instructional quality characteristics, and interactivity characteristics?

Literature Review

Many studies of flipped instruction have focused on its impact on various learning outcomes, presuming that flipped instruction is different in an important way from non-flipped instruction. Some of the studies revealed that secondary students in a flipped section have higher learning gains on their pre- and post-tests than those in a traditional section (e.g., Bhagat, Chang, & Chang, 2016; Charles-Ogan & Williams, 2015), whereas others have shown no differences in learning gains between the flipped and non-flipped sections (e.g., Clark, 2015; DeSantis, Van Curen, Putsch, & Metzger, 2015). In either case, there was insufficient detail with regard to what was happening in the classroom. The authors did not report on the substantive differences between flipped and non-flipped instruction, nor did they draw inferences about which features of the instruction contributed to learning outcomes.

Some studies (e.g., Maciejewski, 2018; Rudd et al., 2017) included classroom observations of the in-class activities but did so generally. For example, Maciejewski (2018) evaluated the effectiveness of a flipped undergraduate calculus course. Students in the non-flipped sections spent more time listening to the instructor, while students in the flipped sections spent more time on individual or group work. In another study, Rudd and colleagues (2017) reported that elementary students in a flipped mathematics section had many opportunities in class to explain what they had learned at home and to solve real-life problems. However, these studies only recorded the types of activities and teacher actions without considering more detailed quality indicators such as conceptual development and interactivity.

In the present study, we look more closely at the lesson implementation in flipped and non-flipped instruction and we add to the growing research base of flipped instruction in secondary mathematics by focusing on Algebra 1. This mathematical setting is important because Algebra predicts the future success of students (Williams, 2011) and mathematical concepts introduced in Algebra are critical for mathematics learning in future mathematics courses (Carraher & Schiemann, 2007).

Theoretical Framework

The framework (Figure 1) of this study draws upon existing frameworks (e.g., Remillard & Heck, 2014; Stein, Grover, & Henningsen, 1996), observation instruments (e.g., MQI, M-Scan), and advice from experts in different fields (e.g., educational technology, mathematics education). Our framework, which is built for a lesson-level scope, allows us to distinguish the different roles that students participate either when viewing the video/multimedia at home or when taking part in in-class activities (Otten et al., 2018). The *in-class* phase captures what occurs during class time, including the *whole-class* and *non-whole-class* activity formats. The *at-home* phase captures the expected activities of students outside the classroom and includes any videos, multimedia, or traditional homework problem sets assigned to students. Within each phase, we focused on certain aspects of the quality of implementation.

We used our framework to develop a classroom observation protocol (Zhao, Han, Kamuru, de Araujo, & Otten, 2018) to capture the general lesson characteristics in terms of focus (what is to be learned), rationale (why is it to be learned), and flow between activities (how the learning activities link together or not). We further distinguished two main in-class components of a lesson, *whole-class* and *non-whole-class* discourse. The *whole-class* discourse is when everyone in the class is expected to be attending to the public discourse regardless of whether it is the teacher (e.g., lecture) or another student (e.g., classroom discussion or student presentation) who is speaking. Within the *whole-class* discourse, we noted the quality of instruction regarding the mathematical development of ideas, integration of mathematical representations, absence of unmitigated errors, and connections to past/future mathematics content. We also focused on the interactivity during the *whole-class* discourse, namely, the exhibited mathematical authority, student public involvement, the sharing/collaborative nature of discourse (Staples & Colonis, 2007), and video/media involvement.

The *non-whole-class* discourse component of our protocol captured time spent when students were expected to work either in groups or independently. We further specified the extent of peer talk, students' use of video/multimedia (e.g., if students watched an instructional video while they were working in class), teacher circulation, and cognitive demand of the tasks. In addition, our framework allowed us to analyze the level of behavioral engagement during the *whole-class* and *non-whole-class* discourse.

For the *at-home* phase, the key video characteristics were examined along three aspects: instructional quality, multimedia design, and interactivity. Instructional quality was the same as described above. The multimedia design was analyzed according to Clark and Mayers' (2008) six digital material design principles: multimedia, modality, contiguity, redundancy, coherence, and personalization. Another aspect, interactivity, documented the interactive elements of the video, such as embedded questions, discussion boards, or virtual manipulatives. More details can be found from Otten, Zhao, de Araujo, and Sherman (in press). Due to the space restriction, the findings of the *flow* and *multimedia design* in this study will not be reported in this paper.

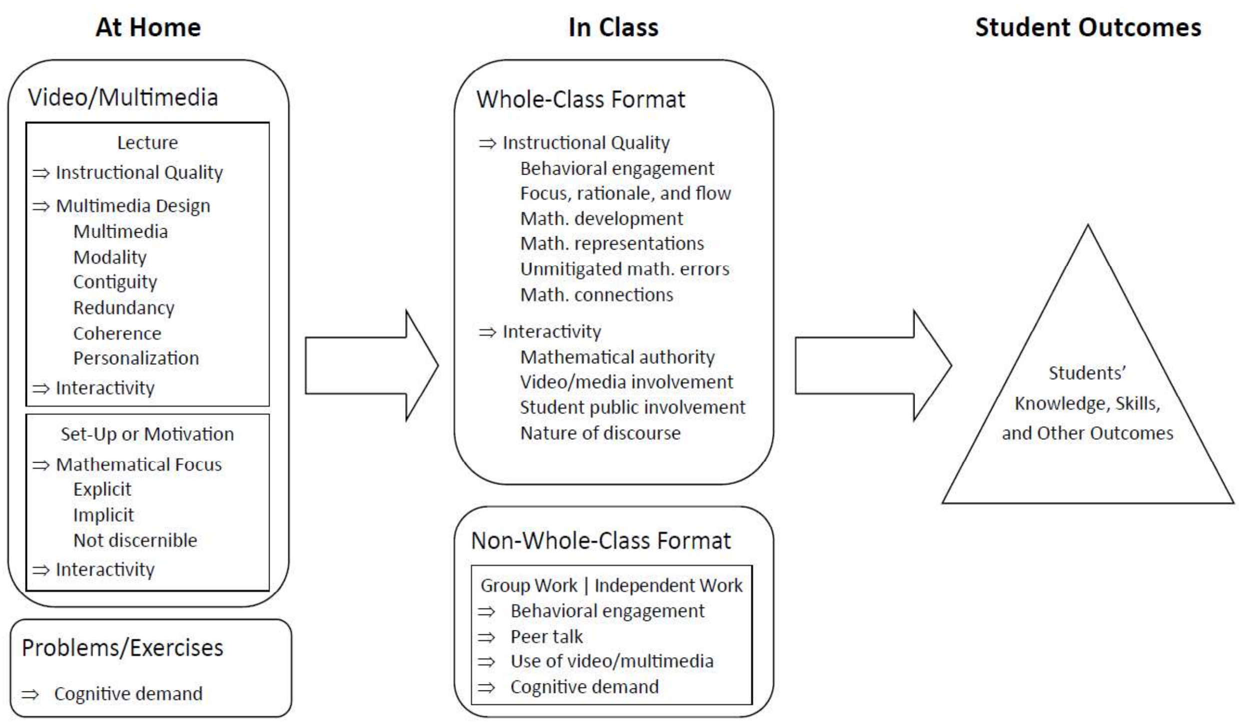

Figure 1: Framework for Flipped Mathematics Instruction (Otten et al., 2018)

Mode of Inquiry

Sample and Setting

The two teacher participants, Mike and Kristen, were both Algebra 1 teachers working at the same public high school in a rural area of Missouri. They worked on the same mathematics team

Otten, S., Candela, A. G., de Araujo, Z., Haines, C., & Munter, C. (2019). *Proceedings of the forty-first annual meeting of the North American Chapter of the International Group for the Psychology of Mathematics Education*. St Louis, MO: University of Missouri.

and shared the same curriculum. Mike has a Bachelor of Science in Mathematics. He had eight years of teaching experience and had been using flipped instruction in Algebra 1 for two years. Mike flipped more than 75% of his lessons but still incorporated non-flipped homework (e.g., problem sets) or sometimes no homework. Mike's class had 22 students who knew the class was flipped when they enrolled, though that may not have been the primary motivation in choosing his class. The other teacher, Kristen, had a Bachelor of Science in Secondary Mathematics Education and nine years of mathematics teaching experience. She had 23 students in her class and was *not* flipping her instruction.

Data Collection and Analysis

The primary data sources for this study were classroom observations and lesson artifacts (e.g., video homework and in-class worksheets). Two researchers observed the classroom instruction three times during a semester using our observation protocol. In this study, we focused on the data from the first classroom observation and examined both teachers' lessons on the rules for operating with expressions that involve exponents (Missouri Learning Standards–A1.NQ.A.1) which is an important topic in Algebra 1. The length of Kristen's lesson was 47 minutes, and the length of Mike's lesson was 47 minutes with an additional seven minutes and three seconds of lecture video assigned to be watched before class. Mike produced the video using a digital pen and a tablet, with an audio voice-over from himself (Figure 2).

Based on the observation protocol, we analyzed the field notes from the classroom observation and coded the interactive features as well as the quality of classroom instruction and the instructional video. A third rater reconciled disagreements between the two raters.

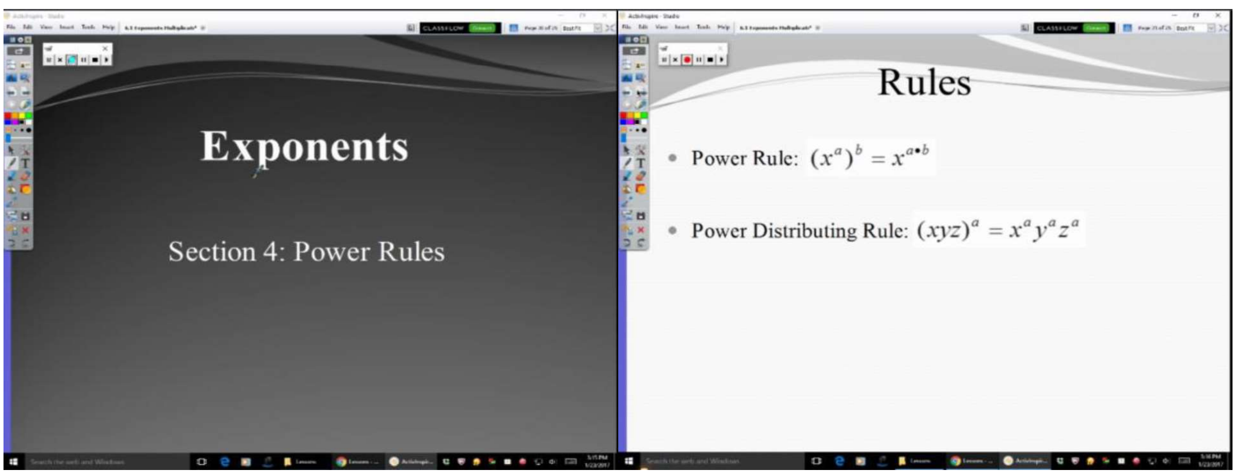

Figure 2: The Lesson Focus on Mike's Lecture Video

Findings

In this section, in our comparison of the two teachers' lessons, we share the research results focusing on the differences and similarities in the (1) lecture video and whole-class discourse, and the (2) non-whole-class discourse phases of the flipped and non-flipped lessons with regard to the instructional quality, interactivity, cognitive demand of the tasks, and student engagement.

Video and Whole-Class-Discourse Phases of the Lessons

Both lessons started with a lecture. Mike's lecture took the form of a video assigned as homework before class, with a brief follow-up in class (i.e., Mike used a whole-class discourse format to go over a few key ideas from the video). Kristen's lecture began when students entered her classroom. Beyond the obvious distinction in the modalities of the lessons (i.e., at-home video vs. in-class lecture), we captured the differences and similarities in terms of the time allocation of in-class activities, lesson focus, rationale, mathematical development, mathematical errors, mathematical connections, use of multiple representations, and nature of discourse.

Differences. As previously mentioned, both lessons began in different physical locations and modalities of interaction. The lecture portion of Mike's lesson started with his seven-minute video. He then spent another eight minutes of class in a whole-class discourse format, for a total of 15 minutes as the first portion of the lesson. A unique piece of Mike's lesson was that his initial whole-class discourse involved several verbal references back to the video, to which students still had access. In contrast, Kristen's lecture was live and started in-person in the classroom. She spent 24 minutes (rather than 15) addressing the class on the content of the lesson and, unlike Mike, she wove this whole-class discourse with brief instances of independent work time (i.e., students tried an example after a worked example).

Similarities. Although there were differences in time allotment, modalities, and spaces of instruction, the teachers had many similarities in their lesson enactments. First, both teachers started their lessons with **content delivery**, which included **an explicit lesson focus** but did not include a **rationale** for why it should be learned. For example, in Mike's lecture video, he started the lesson with the **explicit focus**, "Power Rules," on the screen (Figure 2). Mike mentioned that the lesson would involve learning how to multiply exponents and how to apply power rules and power distributing rules. When the lesson continued into the in-class time, Mike was also clear about the **lesson focus**; he explicitly mentioned that students would continue to learn the properties of exponents. However, in neither the at-home nor in-class phases did Mike give students **a rationale for learning** the rules. Similarly, near the beginning of Kristen's lesson, she displayed a PowerPoint slide that explicitly introduced the **focus of the lesson** and displayed the definition of "Quotient of Powers." Like Mike, however, she too gave **no additional rationale**, such as a real-world application or an expanded understanding of mathematical operations, for why students should learn the lesson.

In terms of the mathematical instructional quality, the lectures were also similar. Both had a **procedural emphasis** with regard to mathematical development. For example, in the video, Mike began by showing the power-to-a-power rule and "power distributing" rule. He then applied the rules to solve problems in which he explicitly directed students to "distribute" the "four" or the "two" as an exponent onto all of the interior terms (Figure 3). Mike did not give reasons for why the rule works. Similarly, Kristen showed the students $\frac{a^m}{a^p} = a^{m-p}$ on the board and worked through three examples. She offered no further explanation other than the procedure that she presented. At no time during the observed lesson did Kristen offer the students a conceptual model to understand the procedures in the lesson.

For both lectures, neither Mike nor Kristen committed any **mathematical errors**. Both teachers referred briefly to the previous lesson, yet neither gave substantial emphasis to the **mathematical connections** between the lessons. For example, Mike mentioned that the new lesson was connected to the previous lesson which only included multiplication of exponents with same bases. However, he did not explicitly explain how the new lesson developed from the previous one. In comparison, Kristen gave her students procedural problems which were a review of the previous lesson as a warm-up before class began. She went over those problems and reminded students of the power rules that they had already covered (e.g., multiplication rule). Then she started her new lesson without any conceptual connection between the previous lesson and the new lesson. In both lessons, the teachers only solved the problems symbolically without attending to other types of **representations** (e.g., tables and graphs) to help students understand the Exponential Rules.

The nature of discourse of both lectures was "sharing" (Staples & Colonis, 2007) because ideas were generally conveyed from the teacher as a source of mathematical authority to the students as receivers. Students were not oriented to each other's thinking or encouraged to connect, extend or critique ideas. Most students only answered in one-word answers or small phrases. For instance, Kristen wrote an equation on the board, $\frac{1c^4d^4f^3}{2c^2d^4f^2}$, then she asked, "What can you tell me about the *d*'s?" The students chorally responded, "Cancel out." We found that leading questions with fixed answers dominated most of both Kristen's and Mike's classroom discourse. The teachers were the **authority** over the mathematics knowledge in both lessons. Kristen and Mike, rather than the classroom community or students, determined the validity of a student's strategy. Overall, **students' public involvement** in both classes was low. Few students asked questions related to the procedures that the teachers worked on the board or responded to the teachers' prompts.

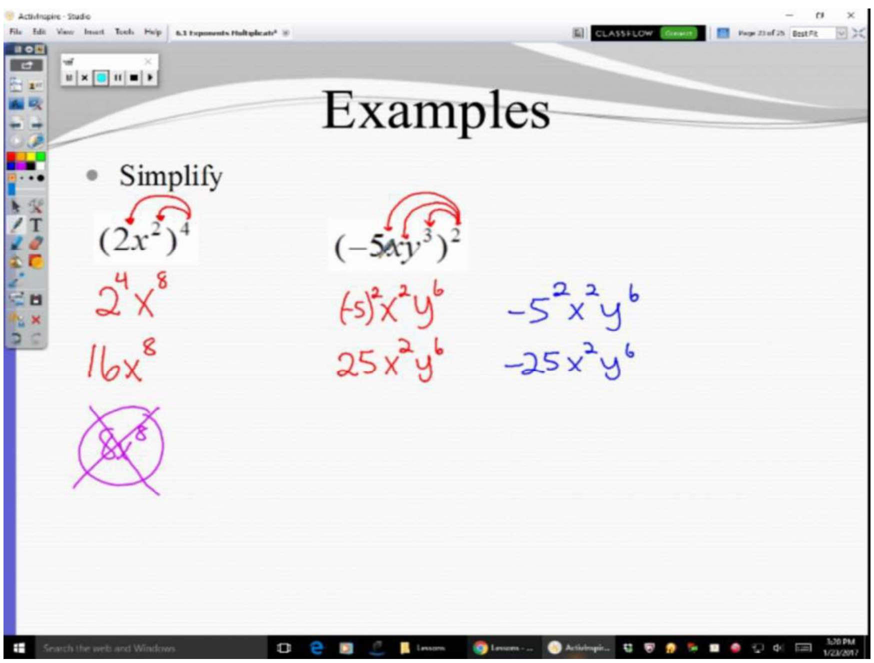

Figure 3: Two Examples in Mike's Lecture Video

Non-Whole-Class-Discourse Phases of the Lessons

For both Mike and Kristen, the lecture or content delivery portions of the lessons were followed by a substantial amount of non-whole-class-discourse (i.e., independent) work time. During the independent time, the teachers were available for questions or even purposely attended to certain students, however, the expectation was for students to work on their own. During this portion of both flipped and non-flipped lessons, we examined three lesson characteristics: the length of the independent work time, cognitive demand of the practice problems, and student engagement.

Differences. The two lessons differed in the amount of time that each teacher allotted for independent work. Because Mike's flipped lesson moved seven minutes of content delivery to the homework assignment, he gave substantially more in-class time for students to work on the practice problems (36 minutes out of 54, or 66.7%). Kristen's lesson, on the other hand, 20 minutes out of 47, or 42.6% was independent work comprising practice after the lecture was completed. Some of Kristen's students finished all the problems during that time, but others were left to finish additional problems at home.

Similarities. It is worth noting that both lessons were similar in the fact that they followed the content delivery portion by then providing students with independent work time for practice problems. The lessons were also similar in that the **cognitive demand** of the practice problems was low. In both Mike and Kristen's classes, they passed out a worksheet with the prompt "Simplify. Your answer should contain only positive exponents." Problems such as $(2m^3)^3$and $(-4n^4)^{-1}$were included in Mike's worksheet. Problems such as $\left(-\frac{vu^4}{2u}\right)^3$and $\frac{(-2x^3y^4)^4}{-2x^4}$were included in Kristen's worksheet. We considered these problems as *procedures without connections* since the main intent of the problems was to produce the correct answer without conceptual connections to the procedure beyond what their teachers had already demonstrated. There was also no explanation or justification required.

The levels of **student engagement** were similar in both lessons. During the students' independent work time, the behavioral engagement was mixed (i.e., many students on task for a majority of the time but also many students off task for at least a substantial portion of the time). In both classes, there were periods where the vast majority of students were working on the practice problems, but in Kristen's class, some were slow to get started and talked to their peers about non-mathematics related topics. In Mike's class, and to a lesser extent in Kristen's class, as some students completed their worksheet, they started to chat with their classmates about non-mathematics related content.

Figure 4 depicts a summary of the two lessons examined in this article.

Conclusion and Implications

The major objective of this study was to compare and contrast the instructional implementations of a flipped and a non-flipped lesson by teachers from the same school using the same curriculum. Many people continue to uphold flipped instruction as an innovative instructional method, which allows teachers to make better use of their in-class time to create more collaborative activities leading to a deeper conceptual understanding of the content. However, as is evident from our analysis, this is not necessarily the case.

Although the modalities of delivery (i.e., in person vs. via video) and the time allocation between the two lessons were different, we found similarities in the instructional quality, interactivity, cognitive demand of the practice problems, and student engagement of both lessons. The flipped instruction, as we examined in this paper, did not move beyond the "video lecture at home and homework in the classroom" model of instruction and in this way remained similar to the non-flipped instruction. Thus, in this case, it seems that merely flipping the spaces and modalities through which content is delivered does not necessarily change the nature of instruction. We invite researchers to be more cautious in crediting flipped instruction as an innovative model of mathematics teaching. Our framework allows us to gain insights into the nuances of similar lessons taught in both flipped and non-flipped classrooms. In reporting future findings of flipped classrooms, we encourage researchers to consider the importance of reporting the details of actual classroom instruction.

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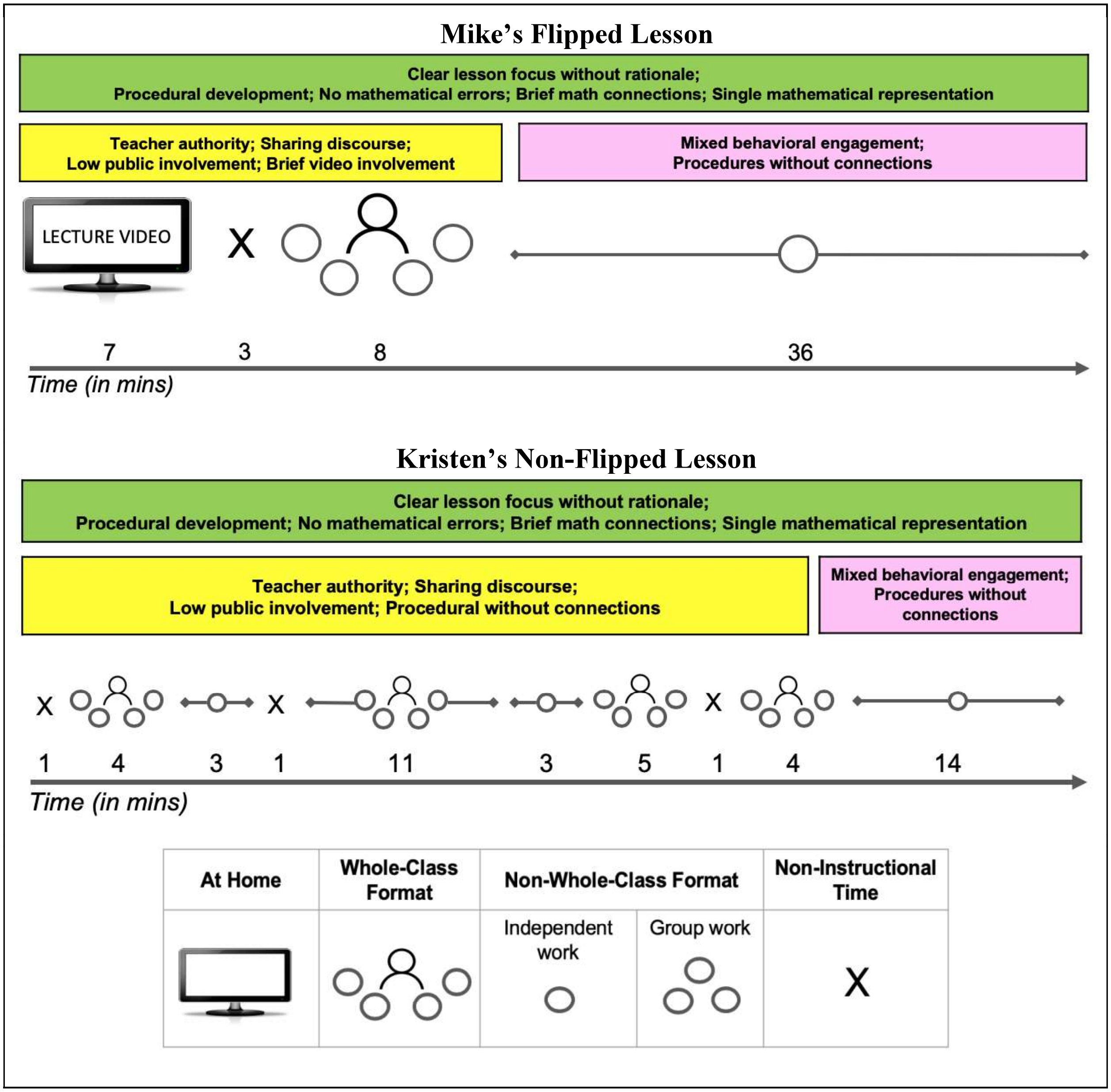

Figure 4: Comparison of the Flipped and Non-Flipped Lesson Implementations

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