

THE POWER OF ACCESS: FLIPPING INSTRUCTION USING STUDENTS'
NATIVE/HOME LANGUAGES IN A SECONDARY ESOL ALGEBRA
CLASSROOM

by

JERNITA MELANIE RANDOLPH-BEAN

(Under the Direction of AnnaMarie Conner)

ABSTRACT

This study investigates the impact of the Flipped Classroom Model (FCM) on multilingual students and explores effective strategies for designing instructional materials tailored to the diverse needs of learners in a secondary algebra classroom. The research is guided by three primary questions: *(1) What are effective strategies for designing flipped mathematics classroom videos that cater to the diverse language backgrounds of multilingual students? (2) How do multilingual learners use videos provided in their native/home language as part of a flipped classroom? (3) How do multilingual learners perceive the use of mathematics videos in their native/home language as part of a flipped classroom approach?*

A case study method was employed to study students' use and perceptions of flipped videos in their native language. This study was conducted at a suburban southeastern high school with a culturally and linguistically diverse student body. Data were collected through classroom video observations, teacher and student interviews, and

student focus group interviews. The findings reveal that incorporating native language videos enhances comprehension and engagement among multilingual students. Effective strategies identified include the use of teacher created videos, explanation of sample problems, review of content vocabulary, and interactive elements that promote active learning. Multilingual learners who used videos in their native/home language demonstrated improved problem-solving skills and students reported feeling more confident and supported in their learning process, contributing to a more inclusive and effective educational environment.

INDEX WORDS: Multilingual learners, English learners, Flipped Classroom Model, Flipped learning, Flipped video design, Case Study, Multicultural students, Secondary mathematics, High school, Algebra, Artificial Intelligence (AI), ESOL, Sheltered instruction, Translanguaging

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DEDICATION

This dissertation is dedicated to the wonderful students who inspired and participated in this study...my “X-Men”. It is also dedicated to my grandparents (Sam and Clara Stubbs, J.D. and Annie Bell Randolph) who laid the foundation for education, discipline, and perseverance. Finally, I dedicate this to every educator who goes the extra mile, pours themselves into their students, and learns just as much as they teach.

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CHAPTER 1

INTRODUCTION

The idea for this study was sparked while I was an Academic Coach at a high school with a majority multilingual, multicultural student population. I went to a classroom to check on a newly enrolled Vietnamese student who was placed in a lower-level mathematics course. He was supposed to be in a higher-level mathematics course, but because of district and state guidelines, he could not be placed in the appropriate course until his transcripts arrived from his previous schools in Vietnam. So, I went to his class, which was an English to Speakers of Other Languages (ESOL) Foundations of Algebra class. Foundations of Algebra was the lowest level of mathematics course offered in high school. The student I was checking on was sitting with a group of students, all working on a mathematics assignment together. I noticed that all the students were talking and collaborating, but I knew they all spoke different home/native languages. I asked the teacher what was happening because I found it extremely interesting, and I was enthralled by their interactions and their engagement with the work, as well as the language shifts that were occurring within the group. I recognized that the entire group was using Hindi as a common language to work on the mathematics assignment. However, none of the students' native/home languages was Hindi, so I was curious as to how that was a language that was selected for them to discuss the mathematics assignment. The teacher explained to me that it was customary for her to go over the mathematics concepts on the board in English and then for the Vietnamese

student to re-teach the concepts in Hindi because many of the other students understood Hindi because they all watched Bollywood movies. I was fascinated...the kids were collaborating, they were engaged, they were understanding, and they had navigated the intricacies of language barriers to come up with a solution to facilitate their learning. At that moment, I thought to myself, “this is what we as educators are supposed to be doing for them,” and then I started to ponder how I could simulate a similar environment (without having clones of a multilingual student with a knack for explaining mathematics). I was already toying with the idea of trying to implement some flipped classroom strategies throughout the building with teachers willing to try flipping their classrooms to create more class time to provide students with opportunities to collaborate and work on more math tasks, and then I thought, “what if some of these videos could be flipped in the students’ native/home language, or in a language that they’re already fluent in?” Could I recreate this moment that I witnessed in the class where there was one student who was able to translate the concepts and information into Hindi so a group of students could understand the concepts explained by the teacher? This became the impetus for this study.

Data show disparities in the academic success and outcomes for students of various ethnic groups and those with limited English proficiency. In their most recent school report, the National Center for Education Statistics (NCES) the 2021-22 school year report for public high school 4-year adjusted cohort graduation rate (ACGR) indicated that the national high school graduation rate was 87 percent (NCES, 2024), which is the highest it has been since the rate was first measured in 2010-11. The percentages across race indicate that Asian/Pacific Islander students had the highest

graduation rate at 94 percent, followed by 90 percent White, 83 percent Hispanic, 81 percent black, and 74 percent American Indian/Alaska Native students. The report also states that the graduation rate of economically disadvantaged students was 81 percent; the graduation rate for students with limited English proficiency was 72 percent.

Despite an upward trend in graduation rates across all ethnic groups, the NCES report, *Status and Trends in the Education of Racial and Ethnic Groups 2018* (de Brey et al., 2019) illustrates distinct disparities among ethnic groups in the mathematics courses taken in high school. For instance, 45 percent of Asian students earned their highest mathematics course credit in calculus compared to 18 percent of White students, 11 percent of students of two or more races, 10 percent of Hispanic students, and 6 percent of Black students. The percentage of students who were 9th-graders in fall 2009 earning any Advanced Placement/International Baccalaureate (AP/IB) credits by 2013 was higher for both Asian students (72 percent) and White students (40 percent) than the percentages for students of any other racial/ethnic group.

Algebra 1 is a foundational course and often determines success in higher mathematics courses. In fact, a student's success in Algebra 1 is often a prerequisite to their ability to enroll in more advanced mathematics courses. According to What Works Clearinghouse (2020), algebra "moves students beyond an emphasis on arithmetic operations to focus on the use of symbols to represent numbers and express mathematical relationships" (p. 1). This use of symbols provides students with the foundational language to study patterns in mathematics; therefore, an understanding of algebra is essential for success in advanced mathematics courses. However, students' difficulties with algebra are well documented. For many students, algebra acts as a gatekeeper to

higher-level mathematics and other STEM courses (Bednarz, 2001; Booth, 1984; Kieran, 2007; MacGregor, 1996; Sharpe, 2019).

The NCES also reports that in 2017, the average score on the National Assessment of Educational Progress (NAEP) mathematics assessment was 40 points lower for 8th-grade English Learners (EL) students than the average mathematics score for their non-EL peers; and in 2015, the average mathematics score for 12th-grade EL students was 37 points lower than the average score for their non-EL peers. These data indicate that a major problem plaguing the American educational system is how to ensure that all students, especially racial/ethnic minority students, and ELs, achieve (Brown-Jeffy & Cooper, 2011).

Diverse students “deserve to engage in curricula designed with their uniqueness in mind. Students cannot be provided with access to curriculum and instruction in isolation of an understanding of cultural context and native language” (Crawford, 2013, p. 267). Schools must shift the traditional environment of the classroom to facilitate equitable accessibility for all students, noting that students’ recognition of teachers’ desires to learn about them beyond the classroom can have tremendous power to motivate them to learn (Bond & Chernoff, 2015; Brown-Jeffy & Cooper, 2011). Using students’ home languages in a flipped classroom model clearly signals the teacher’s commitment to making the information accessible and validates students’ linguistic identities. Flipping the classroom in home languages also provides students “epistemological access without losing access to English” (Setati et al., 2011, p. 15). By moving the direct instruction to videos, teachers can use the class time to create a flexible learning environment in which students can collaborate with their peers. While collaborating, students not only share ideas and

strategies but also practice their English and have increased exposure to the mathematics register. Teachers can provide students with more opportunities to interact with technologies and tasks that can deepen their conceptual understanding of the content. Students develop the confidence to experiment and succeed in an environment where they are not restricted by fear of failure. Moreover, teachers can use culturally relevant examples in instructional videos and in-class activities. By being intentional in the inclusion of students' backgrounds, teachers can demonstrate that they are aware of the distinction between difference and deficiency. In other words, difference does not imply nor translate as deficit and every student's language can be treated as a resource (Brown-Jeffy & Cooper, 2011, p. 68). Analyzing how students leverage information from the videos when provided with mathematics content in their native/home language in this type of setting can assist in promoting efforts to shift the traditional mathematics classroom setting to one that is more inclusive and provides a space for students to explore.

The flipped classroom model (FCM) is most consistently defined as one in which "students engage with lectures or other materials outside of the class to prepare for an active learning experience in the classroom" (Unal, Z. & Unal, 2017, p. 146). These outside materials are most often in the form of instructional videos, note taking, and/or readings. Flipping instruction affords more opportunities for students to access the content because they can watch instructional videos whenever they need to review or refresh a concept (Butzler, 2016; Cevikbas & Kaiser, 2020; Clark, 2015; Crawford, 2013; Freeman, 2011; Katsa et al., 2016; Muir, 2016; Unal, Z. & Unal, 2017). One of the key components of a successfully flipped classroom is the in-class activities. Because

students can watch videos of the lesson(s) outside of class, class time can be used to explore the content in ways that include students' cultural backgrounds and interests. The FCM encourages teachers to provide in-class opportunities for students to collaborate and interact with one another and the teacher, thereby aligning with research that has documented that the preferred learning environment of most minority students, especially African Americans, Latinx Americans, and Native Americans, to be cooperative, collaborative, and communal in nature (Hurley et al, 2005; Ladson-Billings, 1994; Ukpokodu, 2011). Affording diverse learners opportunities to learn while collaborating results in a more positive learning environment and higher student achievement (Ukpokodu, 2011). The FCM not only allows more class time for collaboration, but these collaborations can also allow students to construct their own understandings of the content and how it applies to the world in which they live.

Statement of Problem

The data on multilingual student achievement has not changed significantly over the past 20 years. The NCES (2023) reported that the National Assessment of Educational Progress (NAEP) mathematics score for 12th-grade EL students was lower than the score for their non-EL peers by 41 points. This has been the trend in every assessment year since 2005. These statistics highlight a need for education researchers to explore factors that may contribute to the lower attainment in mathematics by underrepresented minority groups, and more importantly, factors that promote success and attainment of advanced mathematics courses for these same groups.

Despite growing interest by educators in “flipping” the classroom, research on the FCM has not yet established a strong base. There is a plethora of resources available for

teachers who want to implement the FCM; however, there is little empirical evidence confirming the effectiveness of this approach. Only a limited number of studies have examined the experiences of secondary mathematics EL students (Callahan, 2005; Jaquet & Fong, 2017) or the impact of the FCM in a secondary mathematics class (Bhagat et al., 2016; Clark, 2015; Graziano & Hall, 2017; Lo & Hew, 2017) on their learning. Most of the research available on the FCM involves teachers' and students' beliefs about the use of a flipped classroom (e.g., Clark, 2015; de Araujo et al., 2017; Jaquet & Fong, 2017). These studies have found that students enjoy the learning strategies that accompany flipped instruction, such as notetaking, working along with the videos, and answering questions while watching the videos, because these actions help them understand the mathematical concepts better (Graziano & Hall, 2017; Moran & Young, 2015; Unal, Z. & Unal, A., 2017). They also cited a greater degree of student self-efficacy, motivation, and engagement in completing mathematics tasks and participation in classroom discussions. Yet few studies have examined the effectiveness of FCM with diverse learners, especially the in-class activities and the overall instructional design. If this method is going to be used, more research is needed to determine an effective instructional design for implementing the FCM in the mathematics classroom.

There is also limited research on multilingual and multicultural students in secondary mathematics classrooms. There is a growing body of work on ELs, however, the research tends to focus on Spanish-speaking students and/or classrooms where the students speak the same language as one another (Caniglia et al., 2017; Crawford, 2013; Freeman, 2012; Graziano, 2017; Mosqueda, 2010; Thompson 2017). Some of the aforementioned work highlights positive results from student collaborations (e.g., student

self-efficacy, sense-making, development of critical thinking and problem-solving skills), but there is no in-depth analysis of the components of the tasks used or student discussions in a multilingual and multicultural secondary mathematics classroom.

The predominant language of instruction for most students in the United States has been English, and the instructional setting has typically been a traditional Euro-centric approach to learning. This study investigates how the FCM can be used as a viable method for providing ELs access to content and allowing more student agency in the classroom. For instance, by using the FCM with videos in multiple languages and in-class tasks that embed real world application and contextual problems, we can create a curriculum that honors both the mainstream culture and the cultures of diverse learners.

Paris and Alim (2014) provide an eloquent reason for the import of the type of research that I am interested in conducting:

As we reposition our pedagogies to focus on the practices and knowledges of communities of color, we must do so with the understanding that fostering linguistic and cultural flexibility has become an educational imperative, as multilingualism and multiculturalism are increasingly linked to access and power (p. 95).

By demonstrating an understanding that it is vital for all students be given inclusive and engaging mathematical instruction (Bond & Chernoff, 2015, p.25), this research will provide the field with information on another possible method to make the content more accessible to diverse learners. The FCM not only shows promise for student-paced learning; it also can provide an avenue for ELs to access the content. This is especially important in schools/districts with limited ESOL teachers or a large multilingual

population. The FCM provides pedagogical support aligned to an increasing technology-based curriculum design, which is being adopted by many school districts.

Purpose of Study and Research Questions

The purpose of this study was to investigate the impact of the FCM on multilingual students and determine effective strategies for designing flipped classroom instructional materials that cater to the unique needs of diverse learners in a secondary algebra classroom. The study was guided by the following research questions:

1. What are effective strategies for designing flipped mathematics classroom videos that cater to the diverse language backgrounds of multilingual students?
2. How do multilingual learners use videos provided in their native/home language as part of a flipped classroom?
3. How do multilingual learners perceive the use of mathematics videos in their native/home language as part of a flipped classroom approach?

Significance

The literature on effective flipped classroom instructional design is sparse. Most of the current literature addresses teacher and student perceptions about the flipped classroom model or comparative studies of the flipped classroom and traditional classroom instruction. The latter studies are often quantitative studies comparing student achievement in the two different instructional models (Katsa & Sampson, 2016; Li, Z., & Li, J., 2022; Lo & Hew, 2017). My study contributes to the current research by providing an in-depth example of effective flipped classroom instructional design components.

The findings from this study on flipping instruction in a language in which students are fluent can provide valuable insight into designing effective FCM instruction,

including video and other pre-class instruction using FCM. Some of the in-class activities include tasks with multimodal representations to gain a better understanding of how students interpret and interact with the various modes of representation for functions. Understanding the relationship between the different modes of representation in functions leads to a deeper conceptual understanding of the content (Kieran, 2007; Moschkovich 1996; Moschkovich et al., 1993; Schoenfeld, 1991). This research can also provide methods that can be used to scaffold and differentiate lessons, which is extremely helpful given the wide range of educational experiences, and English proficiency levels found in sheltered classrooms.

CHAPTER 2

THEORETICAL PERSPECTIVE AND LITERATURE REVIEW

In this chapter, I state my theoretical perspective and examine the literature relevant to my research questions. Because the focus of the study is to use the flipped classroom model in a multilingual algebra classroom, this section consists of five subsections: theoretical perspective, algebra, multilingual learners, flipped classrooms, and translanguageing. The first subsection defines my theoretical perspective. The second subsection explores the research trends in algebra and theories on algebra instruction. The third subsection discusses effective strategies for teaching multilingual students, and the fourth subsection defines the flipped classroom and its components. The fifth subsection defines translanguageing and its connections to mathematics, multilingual learners and the flipped classroom.

Theoretical Perspective

In my 20 years of education, I have consistently seen the most successful student outcomes occurring in classrooms where students were provided with opportunities to discuss and collaborate on their learning. Therefore, I believe that learning is inherently a social process, and these beliefs align with the sociocultural perspective.

The sociocultural perspective, rooted in the pioneering work of Lev Vygotsky, stands as a compelling theoretical framework that delves into the intricate relationship between social interactions, cultural context, and cognitive development (Vygotsky,

1978). This perspective suggests that individuals' mental processes are not isolated but intricately linked to their social and cultural surroundings.

The Zone of Proximal Development serves as a cornerstone of the sociocultural perspective (Vygotsky, 1978). It delineates the space between what an individual can achieve independently and what can be attained with guidance. Vygotsky proposed that optimal learning occurs within this zone, where individuals engage in tasks with the support of more knowledgeable peers or adults. This concept underscores the importance of social interaction and collaboration in the learning process.

At the heart of the sociocultural perspective lies a profound emphasis on social interaction as a catalyst for cognitive development (Vygotsky, 1978). Interpersonal communication, collaboration, and shared experiences are viewed as essential components shaping an individual's mental processes. The quality of social engagement significantly influences the depth and breadth of learning experiences.

Cultural tools, encompassing language, symbols, and various artifacts, play a pivotal role in mediating cognitive processes (Wertsch, 1991). Language, in particular, serves as a powerful tool through which individuals internalize and express thoughts (Schleppegrell, 2007). The use of cultural tools not only reflects cognitive development but actively shapes it, providing individuals with frameworks for understanding the world.

The sociocultural perspective acknowledges the profound impact of cultural context on cognitive development (Vygotsky, 1978). Different cultures offer unique lenses through which individuals perceive and interpret information. Cultural values,

beliefs, and practices contribute to the diversity in cognitive processes, highlighting the need to consider cultural context in understanding human development.

In conclusion, the sociocultural perspective provides a rich and nuanced framework for understanding cognitive development. By highlighting the interconnectedness of social, cultural, and cognitive factors, this perspective emphasizes the importance of considering diverse contexts in the study of human learning. The Zone of Proximal Development, social interaction, cultural tools, and other key elements collectively contribute to a holistic understanding of how individuals navigate the intricate pathways of cognitive development within their sociocultural milieu. This perspective will frame the following review of the literature.

Algebra: Functions

“Understanding student performance in Algebra I is important because this course serves as the gateway to advanced coursework in mathematics and science through the remainder of high school and into post-secondary education” (Matthews & Farmer, 2008, p. 473). Successful completion of algebra coursework has been shown to lead to improved performance on mathematics proficiency tests, increased understanding of advanced mathematics, and higher enrollment rates in advanced coursework in high school (Bednarz, 2001; Booth, 1984; Kieran, 2007; Matthews & Farmer, 2008; MacGregor, 1996; Sharpe, 2019). Given the foundational role of Algebra, it is crucial to explore effective teaching strategies that can enhance student understanding and performance. One such strategy involves the use of multiple representations, particularly in the context of functions.

Due to their properties, functions are one of the best examples of using multiple representations in the teaching and learning process. Researchers have agreed that functions can be represented in the following forms: algebraic or formulas, tables, verbally, and graphs

(Brenner et al., 1999; Greeno & Hall, 1997; Iannone, 1975; Janvier et al., 1993; Mevarech & Kramarsky, 1997). Traditionally, students have difficulty connecting the properties of a graph to a table and a function's equation. These difficulties start with linear functions and extend to more complex functions. "The linear relationship is the first functional relationship that many students encounter both inside and outside mathematics classes" (Lo & Kratky, 2012, p. 295). However, the formalization of this relationship through symbols and notation and the correct use of this relationship in solving problems present significant challenges for students (Lo & Kratky, 2012, p. 295). A significant contributing factor to this difficulty is the lack of deep understanding of the concept of rate of change (Pierce, 2005; Teuscher & Reys, 2010; Lo & Kratzy, 2012; Soots & Shafer, 2018). Multiple researchers (Pierce, 2005; Teuscher & Reys, 2010; Lo & Kratzy, 2012; Soots & Shafer, 2018) attribute this lack of deep understanding to students' inability to see the interrelatedness of the various representations of the rate of change.

Description of the Content of School Algebra

The National Council of Teachers of Mathematics (NCTM, 2019) has determined that in Algebra, students should be able to: understand patterns, relations, and functions; represent and analyze mathematical situations and structures using algebraic symbols; use mathematical models to represent and understand quantitative relationships; and analyze change in various contexts. For each of these components, students are expected to convert flexibly among and use various representations of functions and interpret these representations (NCTM, 2019). Students are also expected to approximate and interpret rates of change from graphical and numerical data (NCTM, 2019). Additionally, students are expected to create and use representations to organize, record, and communicate mathematical ideas; select, apply, and translate among mathematical representations to solve problems; and use representations to model and interpret physical, social, and mathematical phenomena (NCTM, 2019). A great deal of import is placed on representing, analyzing, and interpreting functions using multiple modes. Therefore, curriculum reforms have moved to emphasizing a need to teach for connections, not just procedural skills. Despite this,

many teachers revert to teaching styles that align with how they were taught and focus more on procedural skills than exploration and providing opportunities for students to make connections.

Teaching Perspectives in Algebra

“Reasoning and sense making are the foundation of mathematical competence and proficiency, and their absence from the curriculum leads to failure and disengagement in mathematics instruction” (Battista, 2017, p. 1). Therefore, sense-making capabilities should be a primary focus of mathematics instruction and curriculum development. To achieve this goal, mathematics classes should provide opportunities for students to engage in activities that promote sense-making.

Multiple representations in teaching Algebra

The literature shows that students can work with different types of representations; however, they have difficulty relating similar information provided by different representations (Accurso et al., 2017; de Oliveira & Cheng, 2001; Elia et al., 2005; Ernest, a,b, &c, 2008; Morgan, 2006; Moschkovich et al., 1993; O’Halloran, 2005,2014, 2015; Swan, 1982; Yerushalmy, 1988). Research reveals student difficulties with transforming from one mode to another and a lack of understanding of how different modes relate to one another. The literature indicates that students rarely connect graphs to real-world models and have difficulty interpreting graphs of functions (Swan, 1982; Yerushalmy, 1988).

Graphs traditionally stood alone in textbooks, and the graph itself was the “solution” to a problem. Students were not asked to analyze the graph or to use it to answer questions about the function (Philipp et al., 1993, p. 249). In my opinion/experience, although graphs have been integrated into the curriculum and students are asked to analyze them or to model situations using graphs, the instruction sometimes falls short because teachers tend to teach graphical representations in isolation.

Janvier and colleagues (1987) present some expectations concerning the uses of multiple representations. They expect, first, that in mathematics problem situations, students should be

able to reject one representation to choose another and know why they made a particular selection. Second, it is expected that students will be able to pass fluidly from one representation to another, understanding the possibilities, limits, and effectiveness of each mode. Third, students should be able to select the appropriate representation considering the task. Finally, using multiple representations, students should be able to grasp the common properties of these diverse materials and succeed in constructing the concept. The tenants of NCTM align with these expectations. NCTM not only acknowledges the import of multiple representations in school mathematics but also indicates that one of the main goals of algebra is that students should “understand the relationships among tables, graphs, and symbols and to judge the advantages and disadvantages of each way of representing relationships for particular purposes” (NCTM, 2000, p. 38). Furthermore, Leinhardt and colleagues (1990) and Moschkovich et al. (1993) affirm that using multiple representations to teach functions, that is, numeric, graphic, and symbolic, will instill a broader understanding of functions.

Gagatsis et al. (2010) indicated that a factor that influences the learning of functions is the diversity of representations related to this concept and claimed that representations could be considered valuable tools for constructing understanding and communicating information and understanding. They stated that a “basic reason for this emphasis is that representations are considered ‘integrated’ with mathematics” (p. 54). Gagatsis et al. (2010) argued that mathematical concepts are accessible only through their semiotic representations. During their study, they observed that translation from graphical to algebraic form was more difficult for students than vice-versa. They correlated this difficulty to students having difficulties making the connections between different representations of functions, interpreting graphs, and manipulating symbols related to functions. Gagatsis et al. suggested that a possible reason for these difficulties is that most instructional practices limited the representations of functions to the translation of the algebraic form of a function to its graphic form and noted that the lack of competence in coordinating multiple representations of the same concept could be seen as an indication for the

existence of compartmentalization, which may result in inconsistencies and delay in mathematics learning at school. Therefore, it is vitally important that teachers are intentional in providing students with instruction that illustrates the multiple ways functions can be represented.

Elia et al. (2005) also found that translation from graphical to algebraic form was more difficult than vice-versa and that the examples given by the students were limited in the graphical and algebraic forms. They also suggested that some students' difficulties in constructing a concept were linked to restricting representations during instruction. Elia et al. (2005) found that students were unable to bridge the algebraic and graphical representations of functions and argued that:

the use of multiple representations in mathematics learning and in this case learning of functions, the connection, coordination and comparison with each other and the conversion from one mode of representation to another should not be left to chance, but should be taught and learned systematically, so that students develop the skills of representing and handling flexibly mathematical knowledge in various forms (p. 183)

Likewise, Hattikudur et al. (2012) noted that graphical representations of functions are integral to algebra and essential in students' mathematics education. However, conveying information with graphs and extracting information from graphs is often challenging for students. Throughout the years, there appears to be a resounding commonality in the difficulties facing students and multiple representations of functions. The literature indicates that despite these difficulties, the intentional teaching and use of multiple representations in mathematics can be used to promote a better conceptual understanding of functions in students.

Sociocultural beliefs in teaching Algebra

Many researchers advocate for creating social environments where the daily practices and rituals in which students engage make it natural for them to internalize mathematics because understanding mathematics involves talking and explaining, false starts, and the interaction of personalities (Moschkovich, 1996; Shoenfeld, 1991; White et al., 2012). They contend that the

classroom is a “cultural milieu in which everyday activities and practices define and give meaning to the subject matter taught” (Shoenfeld, 1991, p.320).

Studies have shown that peer discussions can support the construction of shared descriptions of mathematical objects. Peer discussions create opportunities for students to justify their responses and clarify meanings. Peer discussions also provide a context for students to negotiate shared meanings, and these negotiations can offer a strong impetus for transforming students’ language use (Moschkovich, 1996; Shoenfeld, 1991; White et al., 2012). The social aspect of conversations “shifts learning from an individual location, as in the sociocognitive conflict model, to a social site” (Moschkovich, 1996; p. 273). Peer conversations provide students with multiple opportunities to refine their mathematical descriptions by collaborating and negotiating shared descriptions, thereby enhancing students’ chances of understanding the connection between the algebraic and graphical representations of functions.

Similar to Moschkovich, White et al. (2012) analyzed how students working in a small group packaged together resources, including words, gestures, and inscriptions, into ‘semiotic bundles’ to coordinate their efforts in completing a graphing task. They proposed that overlapping words, gestures, and actions might form ‘semiotic nodes’ where expressive acts in these different modalities work together in social processes of sense-making. During their study, White et al. (2012) determined that students completing tasks in pairs worked to develop shared descriptions of lines by coordinating discourse, gestures, and other conversational resources over time to establish more shared and more mathematically precise ways of interpreting linear graphs. They argue that “mathematical objects are neither idealized entities that preexist our discursive or semiotic activity, nor are they merely constructed through social interactions. Rather, they are socio-historical artifacts, stable forms of culture produced through mediated human activity over long timescales” (p.151). During their study of student groups working on a linear function task, they found that students tended to move from exploratory and visual to more analytic means of establishing lines of a specified slope and that, over time, they enacted these strategies jointly.

During this process, students worked together and discovered the need for coordinated action on their respective points and came to establish mathematical meaning for the relations between their coordinate locations as slope.

In summary, language provides the context; symbolism provides the relationship pattern; diagrams connect the material world to the mathematical processes; and oral language allows students and teachers to make connections in class. Elia et al. (2005) indicated that each one of the “various representations of the notion of function points out a different aspect of the concept and all these together contribute to a global representation of it, and none of them separately can describe the notion entirely” (p. 175-176). By “recognizing the same concept in multiple systems of representations, the ability to manipulate flexibly the concept within these representations as well as the ability to ‘translate’ the concept from one system of representation to another are necessary for the acquisition of the concept and allow students to see rich relationships” (Gagatsis et al., 2010, p. 54).

Multilingual Learners

For too long, our educational systems have privileged some students in the mathematics classroom while marginalizing others. Too often, we have dismissed the assets and strengths of multilingual students while prioritizing English-dominant or monolingual learners. Our policies and practices must be changed to ensure that multilingual learners thrive in the mathematics classroom (NCTM, 2022, p.1).

There are approximately 5 million public school students in the United States who are classified as English learners (ELs) (U.S. Department of Education, 2020). EL students are the fastest growing segment in public education due to the influx of immigrants entering the U.S. educational system; the number of students who speak a native language other than English has grown dramatically and will account for about

40% of the school-age population by 2040 (Berliner & Biddle, 1995). Changing demographics and immigration patterns worldwide merit increased attention to how content area learning can be supported for students in multilingual classrooms; indeed, educating new generations of individuals who are proficient in science, technology, engineering, and mathematics is an issue of global concern (Fensham, 2009).

Accompanied by this increase in a diverse learning population is an increase in concerns about the needs of these students in mathematics classrooms (Celedon-Pattichis & Ramirez, 2012) because mathematics often serves as a gateway to success in the other scientific disciplines.

Mathematics has traditionally been viewed as a content area with minimal language influence; however, it consists of a complex relationship between multiple representations and has a unique vocabulary and syntax known as the mathematical register. “This notion of a mathematical register helps us understand the ways that language constructs mathematical knowledge in different ways than it constructs other academic subjects” (Schleppegrell, 2007, p.140). A major challenge in mathematics instruction is helping students move from every-day, informal ways of constructing knowledge into the technical and academic ways which are essential for disciplinary learning in all subjects. One of the difficulties that students face in learning mathematics is acquiring a proficient understanding of the mathematical register because learning “the language of a new discipline is a part of learning the new discipline; in fact, the language and learning cannot be separated” (Schleppegrell, 2007, p.140). Therefore, considerations of the function of language in mathematics education may prove to be a crucial component to understanding how students learn mathematics.

Research has shown that there is a positive correlation between multilingual students' language proficiency and mathematical performance (Verzosa & Mulligan, 2013; Vukovic & Lesaux, 2013). Studies have also found that although the multisemiotic nature of mathematics is challenging for students (Accurso et al., 2017; O'Halloran, 2005, 2014, 2015; Ernest, 2008; Morgan, 2006; de Oliveira & Cheng, 2001), multimodal instruction positively impacts content mastery in mathematics (Moschkovich, 2012, 2013; NCSM, 2021; Schleppegrell, 2007). Mathematics instruction for multilinguals should employ guidelines for high-quality mathematics instruction and teaching mathematics for understanding. However, because learning is mediated through language, attention should be paid to the type of interactions and opportunities provided for multilinguals to use language (in this case English) in the classroom. Research on learning environments that promote positive outcomes for multilingual students demonstrates that multilingual students benefit from collaborative learning environments and cooperative groups (Merritt et al., 2017; Morgan, 2006; NCSM, 2021; Schleppegrell, 2007; Smith, 2021; Wilson & Smith, 2022).

Collaborative learning encourages students to work together, share ideas, and engage in discussions, which can enhance their language acquisition and comprehension skills (Merritt et al., 2017; Morgan, 2006; Schleppegrell). Research suggests that collaborative activities provide opportunities for multilingual learners to practice language in context, develop communication skills, and build confidence in expressing their thoughts (Merritt et al., 2017; Morgan, 2006; NCSM, 2021; Schleppegrell, 2007; Smith, 2021; Wilson & Smith, 2022).

In these settings, multilingual learners can receive peer support and multiple perspectives on complex topics. Collaborative tasks also encourage active participation, which can be especially helpful for students who might be hesitant to speak in a traditional classroom setting. Although collaborative learning benefits multilingual learners, educators should carefully design activities that balance language proficiency levels and ensure that all participants have a chance to contribute. This approach helps create an inclusive environment that fosters effective learning and positive interactions among students.

A literature review on multilingual learners in mathematics reveals the significance of language barriers in understanding mathematical concepts. Research indicates that multilingual students often face challenges due to limited English proficiency, impacting their comprehension and communication skills in mathematical contexts. Strategies such as incorporating visual aids, real-life examples, and culturally relevant content have shown promise in enhancing multilingual students' mathematical learning experiences. Additionally, teacher training and collaboration between ESOL and math instructors are vital for effective instruction. While progress has been made, further research is needed to explore the nuanced interactions between language and mathematics learning for multilingual students and to develop more comprehensive instructional approaches.

Flipped Classroom Model

There is existing literature on language acquisition and EL instruction; however, there is limited literature on mathematics instruction for ELs at the secondary level in multilingual classrooms. Advancements in technology have led to its increased use as a pedagogical delivery method, and there is considerable literature about the use of flipped

classrooms, but there is little research published about the use of the flipped classroom model in secondary mathematics. The literature on the use of a flipped classroom model in a secondary sheltered mathematics classroom is even rarer still. A sheltered class refers to a specialized class designed specifically for English Learners, where the curriculum is modified to make the content more accessible by using visual aids, simplified language, and other strategies to support their understanding of the subject matter while they are still developing their English proficiency. To contribute to filling this gap, the present study will examine the usage of the flipped classroom model on mathematics concept learning in a multilingual high school sheltered mathematics classroom.

Although traditional lecture-based teaching has historically been the norm in secondary mathematics education, educators and researchers now recognize the need to introduce collaborative, inquiry-oriented learning pedagogies like the flipped classroom model (FCM) to foster a deeper conceptual understanding of the content (Love et al., 2014). Such approaches can positively impact students' success in their current course and in subsequent courses. One of the key benefits of these approaches, as opposed to traditional lectures, is the focus on students' engagement, participation, and conceptual understanding. Thus, the teacher may facilitate students' collective efforts to become participants in the mathematical problem-solving community (Xu et al., 2022; Kuiper et al., 2015; Zhu, 2021). The flipped classroom model is most consistently defined as one in which “students engage with lectures or other materials outside of the class to prepare for an active learning experience in the classroom” (Unal & Unal, 2017, p. 146). The Flipped Learning Network (2014) states:

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. (p.1)

They also describe flipped learning as having four pillars: “a flexible environment, learning culture, intentional content, and a professional educator” (p.2).

Current literature lists the benefits of the flipped classroom model of instruction as: (1) students move at their own pace, (2) doing ‘homework’ in class gives teachers better insight into student difficulties and learning styles, (3) classroom time can be used more effectively and creatively, (4) teachers using the method report seeing increased levels of student achievement, interest, and engagement, (5) provides students with more opportunities for collaboration and deeper conceptual exploration and (6) the use of technology is flexible and appropriate for 21st-century learning (Crawford, 2013; de Araujo, Otten, & Barisci, 2017; Feng, & Chen, 2022; Freeman, 2011; Katsa et al., 2016; Kirvan et al., 2015; Kuiper et al., 2015; Song & Kapur, 2017; Unal et al., 2017; Zhu, 2021). During my analysis of the FCM research, in addition to the benefits listed above the following affordances also emerged: more opportunities for differentiation and scaffolding; increased student motivation; optimization of class time; positive perception and attitude toward mathematics; and increased self-efficacy and confidence (de Araujo, Otten, & Barisci, 2017; Feng, & Chen, 2022; Katsa et al., 2016; Kirvan et al., 2015; Kuiper et al., 2015; Lo, 2017,2018; Song & Kapur, 2017; Unal et al., 2017; Zhu, 2021).

Despite the large body of work focused on multilingual students, the research literature focused specifically on the performance of secondary multilingual learners in mathematics is still somewhat limited. However, there are a few studies that report on the benefits of using technology (Crawford, 2013; Freeman, 2011) and the FCM (Graziano & Hall, 2017) to promote multilingual student achievement. The results from these studies indicate flipped instruction and the use of technology engaged students and

motivated them to learn. Both Crawford (2013) and Freeman (2011) determined the use of technology and self-paced online tutorials increased multilingual learners' understanding of mathematics. Results from Graziano and Hall's (2017) study revealed students enrolled in the flipped course performed slightly higher than their peers who received traditional instruction.

As stated in Chapter 1, the FCM is defined as one in which students engage with lectures or other materials outside the class to prepare for an active learning experience in the classroom. Students can view the videos or review the content as many times as they need to in order to understand the content. Class time can be used to clear up misconceptions and delve deeper into the content with the support of the teacher and peers. The use of the FCM could, therefore, provide students with more opportunities to interact with both the teacher and their peers to explore the content and thereby promote deeper conceptual understandings. However, it is imperative that flipped lesson activities are intentionally designed to help students make conceptual connections and provide spaces for student collaboration.

Effective Flipped Classroom Instructional Design

The flipped model argues for replacing the teachers' lecture during the classroom sessions with appropriately designed learning materials that can be studied by the students at home in a more self-paced manner (Xu et al., 2022; Katsa et al., 2016; Zhu, 2021). It provides a means of enhancing student-centered teaching approaches and delivering better students' learning experiences and conceptual understanding (Xu et al., 2022; Katsa et al., 2016; Kirvan et al., 2015; Kuiper et al., 2015; Unal, Z. & Unal, 2017; Zhu, & Huang, 2021). Typically, the homework in the FCM consists of students watching short online lecture videos created or selected by their teachers (de Araujo, Otten, and Barisci, 2017; Xu et al., 2022; Katsa et al., 2016; Kirvan et al.,

2015; Kuiper et al., 2015; Song & Kapur, 2017; Unal, Z. & Unal, 2017). The premise behind this process is to use homework time to provide students with an opportunity to begin thinking about the mathematical concepts they will encounter in class and to use class time to focus on assessing student understanding and providing them with opportunities to engage in more enriching activities (Xu et al., 2022; Kirvan et al., 2015; Zhu, 2021). In addition to the use of videos, some teachers opt to assign reading assignments or guided notes to complete using their textbooks (de Araujo et al., 2017). In FCM, the intent is for most of the class time to be spent on group learning activities that focus on applying the knowledge learned from the video lectures, such as solving advanced problems with the support of the teacher and peers or working on tasks (Xu et al., 2022; Unal, Z. & Unal, 2017; Zhu, 2021). In theory, the flipped classroom moves the responsibility of knowledge acquisition to the learner, and the teacher then becomes responsible for guiding student learning as a facilitator rather than the transferer of information (Butzler, 2016; Song & Kapur, 2017; Unal, Z. & Unal, 2017). In a flipped classroom, the “teacher is present in real time to support and guide students as they practice or apply the knowledge and skills developed in the content delivery portion of the lesson” (de Araujo et al., 2017, p. 68).

The definition of the FCM provided by the Flipped Learning Network (2014) indicates that the purpose of moving the direct instruction to the individual learning space is to open the group space to become an interactive learning environment where the educator guides students as they apply concepts and engage creatively in the subject matter (p. 1). Merely reordering the teaching and learning activities is insufficient to represent the practice of an effective flipped classroom approach (Xu et al., 2022; Song & Kapur, 2017; Unal & Unal, 2017; Zhu, 2021). If the traditional way of instruction (direct instruction) remains unchanged except that a video is created, and the time spent on the lecturing in class is performed at home without any changes to the in-class activities and instructional design, then the FCM will likely mimic the same results as traditional in-class lectures. It is important to pay close attention to Flipped Learning Network’s (2014) definition of the FCM, especially the portion concerning the group space being

transformed into a dynamic, interactive learning environment and the professional educator guiding students as they apply concepts and engage creatively in the content (p. 1). Careful consideration and intentional design of the pre-class, in-class, and post-class activities are paramount to implementing a successful flipped classroom.

Pre-class Design

The pre-class activity often involves watching a video. However, a flipped classroom entails more than simply assigning videos and then allowing students to do homework in class (Bhagat et al., 2016; Bergmann & Sams, 2012; de Araujo et al., 2017; Xu et al., 2022; Katsa et al., 2016; Song & Kapur, 2017; Unal & Unal, 2017; Zhu, & Huang, 2021). Careful consideration needs to be given to the videos being assigned, and the videos should succinctly and eloquently detail the targeted concept. Videos should only be 5-10 minutes long and have an interactive component assigned or embedded within them (de Araujo et al., 2017; Katsa et al., 2016; Kirvan et al., 2015; Kuiper et al., 2015; Song & Kapur, 2017; Unal & Unal, 2017). Keeping the videos short forces teachers to focus on being clear and concise. Opportunities to take notes and practice sample problems should be embedded in the pre-class activities (de Araujo et al., 2017; Graziano & Hall, 2017; Katsa et al., 2016; Kirvan et al., 2015; Kuiper et al., 2015; Song & Kapur, 2017; Unal & Unal, 2017). In their study of a secondary algebra classroom, Graziano and Hall (2017) reported that “students enjoyed the learning strategies that accompanied flipped instruction such as note-taking, working along with the videos, and answering questions while watching the videos” (p. 14). Students stated that these strategies helped them learn the content.

To ensure that flipping is effective, students need explicit instructions on the steps involved and guided practice for understanding the process and expected outcomes of the flipped classroom model (Xu et al., 2022; Moran & Young, 2015). A component of these explicit instructions should include detailing the goal of the flipped classroom approach as well as its routines and procedures for both the in-class and out-of-class activities (Xu et al., 2022; Moran & Young, 2015; Unal, Z. & Unal, 2017). Teachers need to demonstrate to students how to learn

through the flipped classroom model of instruction. Active viewing of the instructional videos “requires implementing scaffolded strategies so students can interact with and process the digital videos they are viewing effectively” (Moran & Young, 2015, p. 45). Some of these strategies could entail guided note-taking, pause and ponder questions, guided practice problems, and dynamic mathematics tools such as Desmos (2011) and GeoGebra (2023). The pre-class activities should act as a prelude to the in-class activities and align with the in-class lesson.

In-class Design

The in-class activities of a flipped classroom should provide students with opportunities to ask questions, explore mathematical concepts, and collaborate with peers. The beginning of class can consist of a mini-lecture reviewing the information shared in the video to provide an opportunity for students to ask questions and to explain the expectations for the in-class activity (Lo, 2017, 2018; Lo & Hew, 2017; Fung, et al., 2021; Strayer et al., 2016). After students have an opportunity to ask questions and clear up possible misconceptions, then they can engage in a learning activity. This activity or task should build on the concepts covered in the pre-class activity. During this time students can consolidate what they learned while working on a problem individually or in pairs (Lo & Hew, 2017). While students are working, the teacher should be circulating through the classroom providing students feedback on their work. The in-class tasks should scaffold up in complexity (Lo, 2017, 2018; Lo & Hew, 2017; Strayer et al., 2016) from procedural problems to tasks allowing students to apply their knowledge in solving more advanced or real-world problems in groups with the support of the teacher and peers.

In their systemic reviews of the research on flipped classrooms in mathematics, Lo (2017) and Fung et al. (2021) determined the most effective outcomes in a flipped mathematics classroom involved in-class activities, allowing students opportunities to interact and collaborate with each other. Other researchers also observed that flipped classroom studies entailing student discussion, teachers’ feedback, and peer collaboration during the in-class activities demonstrated higher academic gains than the comparative traditional classrooms studied (de Araujo et al.,

2017; Graziano & Hall, 2017; Katsa et al., 2016; Kirvan et al., 2015; Kuiper et al., 2015; Song & Kapur, 2017; Strayer, et al., 2016; Unal & Unal, 2017). These interactions should extend beyond the small group collaborations to the whole group discussions. These whole group discussions should provide students opportunities to share their small group findings and problem-solving strategies/approaches. These group discussions could deepen students' understanding and help them integrate the new knowledge into real-world contexts (Lo & Hew, 2017; Warter-Perez & Dong, 2012).

Post-class Design

The current literature is thin regarding effective post-class activities. The studies that do mention post-class activities agree that the activities should provide students with an opportunity to consolidate their learning. These activities could include some form of a reflection activity for the lesson, homework problems, discussion posts, or additional videos to enhance the content covered in class (Li & Li, 2022; Lo & Hew, 2017).

Translanguaging

Translanguaging is an innovative approach in education that recognizes and values the diverse linguistic resources students bring to the classroom. It involves the seamless and purposeful integration of multiple languages within teaching and learning activities (Aleksić & García, 2024; García & Kleyn, 2016; Hamman-Oritz et al., 2025; Wei, 2017). By encouraging students to draw on their entire linguistic repertoire, including their native language(s), translanguaging promotes deeper understanding and engagement in the educational process (Aleksić & García, 2024; García & Wei, 2014; Hamman-Oritz et al., 2025). This approach recognizes that language is a dynamic tool for communication and cognitive development. By allowing students to use their native language alongside the target language, translanguaging facilitates comprehension, critical thinking, and higher-order problem-solving skills (García, 2009; Li, 2020). It also fosters a sense of belonging and cultural identity, as

students' language and cultural backgrounds are acknowledged and respected (Aleksić & García, 2024; García & Wei, 2014; Wei, 2021). Translanguaging has been shown to support English language learners, bilingual students, and students from linguistically diverse backgrounds in achieving academic success while maintaining and developing proficiency in multiple languages (García & Kleyn, 2016; García & Wei, 2014; Li, 2020; Wei, 2021).

Translanguaging and Mathematics

Translanguaging in mathematics instruction is an emerging area of research that explores the benefits of integrating students' native language(s) alongside the target language during mathematical learning activities. Translanguaging approaches have been found to enhance students' understanding and engagement in mathematics, particularly for bilingual and multilingual learners (Moschkovich, 2020). By allowing students to use their native language(s) to make connections, explain concepts, and solve problems, translanguaging fosters deeper comprehension and conceptual development (Percy et al., 2022). Furthermore, translanguaging promotes the development of metalinguistic awareness, as students compare and contrast mathematical terminology and concepts across languages (Ossa Parra & Proctor, 2021). This approach not only supports students' mathematical learning but also preserves and reinforces their linguistic and cultural identities within the mathematics classroom. By embracing translanguaging, educators can create inclusive and effective learning environments that capitalize on the rich linguistic resources of their students.

FCM and Translanguaging

The integration of translanguaging and the flipped classroom model can provide several benefits in language learning and student engagement. It allows students to access and process content in a language they are most comfortable with, facilitating comprehension and knowledge retention (Baker & Wright, 2017). This integration also promotes active engagement, as students can analyze and discuss the material in their native language(s) before interacting with peers in

the target language during class time (García & Kleyn, 2016). Students can use translanguaging to collaborate on in-class activities using the information gained from watching instructional videos outside of class.

The flipped classroom model combined with incorporating videos in students' primary language allows students to interact with the content prior to class as well as view and pause the videos as many times as they need to learn the material. This affordance provides more in-class opportunities for students to discuss what they learned. Translanguaging in the flipped classroom helps students make connections between languages and deepen their understanding of complex concepts. They can draw upon their linguistic repertoire to clarify concepts, compare vocabulary, and bridge the gap between languages, enhancing their overall comprehension and critical thinking skills (García, 2009).

By incorporating translanguaging in the flipped classroom, educators create a more inclusive and culturally responsive learning environment. Multilingual students feel validated and recognized for their linguistic abilities, fostering a positive classroom climate that supports their language development and academic success (García & Kleyn, 2016).

This study aims to investigate what happens when integrating students' home languages with the flipped classroom model by offering students the opportunity to engage with instructional content in their native language(s) before participating in interactive classroom activities. This approach seeks to enhance comprehension, critical thinking, and inclusivity, thereby enriching language learning and student engagement. By examining effective strategies for designing flipped classroom materials that cater to the diverse linguistic backgrounds of multilingual students, the study aims to uncover how these students utilize and perceive the inclusion of their home languages within the flipped classroom framework.

CHAPTER 3

METHODS

In this chapter, I describe the methods that I used to answer my research questions. I used a qualitative case study to investigate the impact of the FCM on multilingual students. This study seeks to determine effective strategies for designing flipped classroom instructional materials that cater to the unique needs of diverse learners in a secondary algebra classroom and how they affect student motivation and confidence. To achieve this goal, this study poses the following research questions:

1. What are effective strategies for designing flipped mathematics classroom materials that cater to the diverse language backgrounds of multilingual students?
2. How do multilingual learners use videos provided in their native/home language as part of a flipped classroom?
3. How do multilingual learners perceive the use of mathematics videos in their native/home language as part of a flipped classroom approach?

A case study method was employed to study students' use and perceptions of flipped videos in their native language. Yin (2003) noted that a case study is "the preferred strategy when 'how' or 'why' questions are being posed, when the investigator has little control over events, and when the focus is on a contemporary phenomenon within some real-life context" (p. 1). A case study is an appropriate tool to investigate the phenomena of how students use videos provided in their native/home language as part of a flipped classroom because it offers an opportunity to learn from teacher and student experiences.

Site Selection and Participants

This study was conducted at a suburban southeastern high school in a culturally and linguistically diverse community. The high school has an enrollment of 1312 students, and 1118 of the students are considered EL, although not all the EL students are coded as needing language support services. The student population consists of 7.3% Hispanic/Latino, 0.29% American Indian, 30.7% Asian, 54.4% Black or African American/African Descent, 0.5% Native Hawaiian/Pacific Islander, 5.7% White not of Hispanic origin, and 1.1% Multiracial students. The community surrounding the school has a large immigrant population, and the students are from over 54 different countries and speak 47 different languages, not including regional and tribal dialects.

The district in which the school is located has a technology initiative to ensure that every student in the district has a Chromebook. The high school in this study was selected to be one of the pilot schools for the technology initiative, so students have Chromebooks and can also apply for free hotspots so they can have internet access at home. Both the district and the school administration are encouraging teachers to embed technology activities into their lessons, so the use of a flipped classroom was considered a favorable instructional strategy. The study took place in a 9th Grade ESOL Algebra classroom. Classroom observations were conducted prior to implementing the flipped lesson so I could familiarize myself with the students and allow them to become comfortable with me. These observations also allowed me to observe the whole class and small group dynamics as well as individual student behaviors. I used these classroom visits as an opportunity to build a rapport with the students by not only helping with their questions about the classwork but also discussing our common interest in anime cartoons.

Classroom observations were conducted during the instruction of Algebra: Concepts and Connections, Unit 4: Modeling and Analyzing Quadratic Functions. I observed classroom interactions between the teacher and the students and the interactions of three small groups while they worked on tasks. The teacher is a White male with 14 years of teaching experience and 11 years of ESOL teaching experience. I had a previous coaching relationship with him and was very familiar with his teaching style, and he was comfortable having me in his class. The students have diverse educational backgrounds; some have attended school regularly and others have had breaks in or no prior educational experience.

This teacher's class was chosen for the study because, despite the complexities of having to teach multilingual and multicultural students from various educational backgrounds, this teacher has demonstrated one of the largest student achievement growth percentages in the building. His achievement growth percentages have been attributed to his consistent use of collaborative groups and rich student discourse. This was of particular interest to me because my study involved observing small group interactions after students watched the flipped videos. The teacher selected was also interested in working with me to create the videos for his students and was excited about being a part of the study in general.

After consulting with the teacher, we decided the study would occur in his third block Algebra: Concepts and Connections class. Third block was the lunch block, so the class time was broken up by lunch. There were 25 minutes of instructional time prior to lunch and 65 minutes of instructional time after lunch. This block was chosen because most of the students in this class were taking Algebra for the first time, and students in

this block had enough English proficiency to participate in the student and focus groups interviews. Using teacher recommendations, my own observations, and who was available based on the consent forms, I initially selected two student focus groups for the classroom observations. During the second flipped lesson a third group of students asked to participate in the study, allowing me to observe their interactions in class. Focus Group 1 (FG1) was a heterogeneous language group consisting of five students with different home languages. Two of the students' home language was Zo, one student's home language was German, one student's home language was Swahili, and one student's home language was Tigrinya. Focus Group 2 (FG2) was a homogenous language group consisting of four students with similar languages, Pashto and Urdu. The student whose home language was Pashto was also fluent in Urdu. Student Group 3 (SG3) was a heterogeneous language group consisting of three students with different home languages. The students in this group did not participate in any of the interviews, so I did not capture their demographic information. The students' interview participation and group assignments can be found in *Table 1*.

Table 1*Interview Participation and Small Group Assignment*

Student	Individual Interview After FCM1	Focus Group Interview After FCM1	Individual Interview After FCM2	Focus Group Interview After FCM2	In Class Small Group
Hank	Yes	Yes	Yes	Yes	2
Emma	Yes	Yes	No	No	1
Remy	Yes	Yes	Yes	Yes	1
Jubilee	No	No	Yes	Yes	1
Ororo	Yes	Yes	Yes	Yes	1
Raven	No	No	No	No	1
Scott	No	No	No	No	2
Kevin	No	No	No	No	2
Anna	No	No	No	No	3
Bishop	No	No	No	No	3

The student participant demographic information can be found in *Table 2*. Other considerations for selection were attendance and previous participation in small group discussions.

Table 2*Student Participant Demographics*

Student	Age	Home Language	# of languages spoken	# of Years speaking English	Years of schooling	Watched videos prior to study
Hank	17	Pashto	4	3	3	No
Emma	15	Zo	5	5-6	9	Yes
Remy	16	Zo	2	10	10	Yes
Jubilee	16	Tigrinya	2	15	10	Yes
Ororo	15	Swahili	3	9	9	Yes

To maintain the confidentiality of the participants I assigned pseudonyms based on X-Men characters. I chose these pseudonyms instead of assigning numbers or

pseudonyms from their different cultural backgrounds because (1) I wanted to highlight the participants' individual personalities and (2) when I was establishing a rapport with the class, we would discuss various anime shows including X-Men. As I worked with the class distinct personalities quickly emerged and I was able to “see” each of the students as a distinct X-Man. Both the teacher and the students thought this was a cool idea, so I proceeded with using X-Men pseudonyms. Let me introduce you to my X-Men:

Professor X (Charles Xavier) The founder of the X-Men, Charles Xavier is a powerful telepath and visionary. He dedicates his life to fostering peace between mutants and humans, believing education and understanding are key. As a mentor and father figure, Professor X inspires his students to embrace their powers responsibly, but his idealism is occasionally challenged by the harsh realities of their world. He uses his immense powers to guide, educate, and protect his students while advocating for understanding in a world rife with prejudice.

Similarly, Professor X was fully committed to ensuring his students learned. He was willing to stay late, come on Saturdays for tutorials, advocate for them, and try different ways to help his students learn the content. He was excited about participating in my study because he wanted to give his students more resources to learn. He viewed the diversity of his students as an asset and believed they could perform at the same level as native English speakers if they were given the appropriate tools. This dedication to education and advocacy mirrors Charles Xavier's commitment to fostering understanding and guiding his students in a world filled with challenges.

Beast (Dr. Henry “Hank” McCoy) Beast is a brilliant intellectual with an insatiable curiosity for science, philosophy, and the arts. His refined, cultured nature stands in stark

contrast to his physically imposing, blue-furred appearance, creating a poignant duality. While he is often the voice of reason and calm in the X-Men, Beast occasionally struggles with self-acceptance and fears how society perceives mutants. His dry humor and love for quoting classic literature reveal a gentle and compassionate soul, and his dedication to advancing mutant kind through knowledge and diplomacy is unwavering. Beast is often the team's moral compass, offering sage advice and devising solutions to complex problems.

Similarly, the student I refer to as Beast/Hank was initially regarded as apathetic by his teacher and classmates. However, this initial view was proven incorrect over the course of the study. Much like the X-Men's Beast, he quickly emerged as an engaged, hardworking individual who encouraged his group mates to view the videos and participate in the flipped lesson activities. By the end of the study, both the teacher and his classmates viewed him as an integral part of the class discussions. He became an “ambassador” for the use of the translated flipped videos to promote content understanding, demonstrating a dedication to learning and collaboration that mirrored the intellectual and compassionate nature of his namesake.

Rogue (Anna Marie LeBeau) Rogue/Anna has the power to absorb the memories, abilities, and life force of anyone she touches. Initially, a troubled soul due to her uncontrollable powers, she found a family with the X-Men. Rogue is fiercely independent, brave, and protective of her teammates, often relying on her southern charm and wit.

Similarly, the student referred to as Rogue is fiercely independent and strong-willed. She quickly understands the content, much like Rogue's ability to absorb

knowledge and abilities. However, she sometimes overestimates her understanding of English and can become frustrated when she misunderstands a concept due to the language barrier. Despite this, she is a group leader who strives to ensure her entire group comprehends the concepts and assignments, mirroring Rogue's protective nature and dedication to her team.

Mystique (Raven Darkholme) A shapeshifter with the ability to assume any appearance, Mystique is as enigmatic as she is deadly. Often walking the line between hero and villain, her cunning mind and combat skills make her a formidable adversary. Her deep connections to other mutants, particularly Nightcrawler and Rogue, give her story complexity.

The Mystique/Raven in this study fluctuated between working alone and working with the group. Like Mystique, she was initially guarded but slowly integrated into the group. Her class participation “appearance” vacillated between wanting to be “cool” and aloof and fully participating with her group mates. Similar to the character Mystique, once she connected to her group members she was fully engaged in the group and diligently worked with them to complete her assignments. In true “Mystique” form, she agreed to participate in the individual and focus group interviews but disappeared before I was able to conduct them.

Jubilee (Jubilation Lee) A young, spunky mutant, Jubilee generates explosive energy bursts that resemble fireworks. Her upbeat personality and loyalty make her a cherished member of the team. She often serves as the “heart” of the group, providing levity during dark times and proving her courage in battle.

Similarly, my Jubilee was also spunky and upbeat. She had a vibrant personality and meshed well with her classmates. She was easy-going and actively engaged with her group, much like Jubilee's role in the X-Men. She would ask questions that her group may have been timid about asking, never fearing embarrassment. She joked around, lightening the mood but also actively engaged in the work, reflecting Jubilee's ability to provide levity and courage in challenging situations.

Gambit (Remy LeBeau) Gambit is a suave and mysterious mutant from New Orleans with the power to charge objects with explosive kinetic energy, often using playing cards as weapons. He is both a rogue and a romantic, often acting as the team's wildcard. His confidence, wit, and flirtatious demeanor contrast with his inner struggles to reconcile his past with his role as an X-Man. Despite his devil-may-care attitude, Gambit is fiercely loyal and willing to make sacrifices for those he loves.

Likewise, my Gambit/Remy appeared to be quick-witted and unbothered. He pretended to be disinterested in his group and only concerned about himself. He would work on his assignment, seemingly engrossed and self-absorbed, only to look up and ask group members what was wrong or if they needed help. Similar to the character Gambit, if he saw a group mate struggling with a problem, he would stop what he was doing and help them by explaining a problem or concept. He was patient and thorough in his explanations, not returning to his work until he was satisfied, they understood how to solve the problem. This mirrors Gambit's hidden depth and loyalty, showing that beneath his carefree exterior lies a dedicated and supportive teammate.

Storm (Ororo Munroe) Storm is a natural leader with a regal and commanding presence, exuding both strength and grace. She possesses an innate connection to nature,

controlling weather with precision and empathy. Despite her immense power, Storm is deeply compassionate, often acting as a mentor and protector for her teammates. She is calm under pressure and fiercely loyal. Her deep empathy for others and strong moral compass makes her an inspiring figure.

Similarly, like mutant Storm, FCM Storm/Ororo was a natural leader with a quiet strength and grace. She was keenly in tune with her group and their needs, possessing a deep desire to help other students and readily assisting others in the class. She persevered through difficult problems without becoming frustrated, never letting a lack of understanding prevent her from trying or helping other students understand. She used every resource available to her to gain a better understanding of the content and encouraged other students to use them as well by guiding them to the appropriate resources. This mirrors Storm's deep compassion, tenacity, and ability to inspire and support her teammates.

Emma Frost Once an enemy of the X-Men, the telepathic and diamond-skinned Emma Frost has evolved into a powerful ally and mentor. With a sharp intellect, wit, and unyielding confidence, she serves as a strong strategist for the team while mentoring younger mutants to harness their powers.

Similarly, FCM Emma was fiercely confident and did not like to be perceived as not knowing or understanding. Much like Emma Frost, she presented with a tough exterior and was confident in her ability to do the work. She persevered through challenges and worked well with her group, often providing witty one-liners as they worked through assignments. This mirrors Emma Frost's sharp intellect and unyielding confidence, as well as her ability to mentor and support her team.

Morph (Kevin Sidney) Morph has the ability to shape-shift into any form, making him a key asset for stealth missions. Known for his humor and lighthearted nature, Morph uses his powers to bring levity to the group, but his experiences often reveal hidden depths and emotional struggles.

FCM Morph/Kevin was a part of Focus Group 2, which was regarded as the jokesters. He would crack jokes and play around during class, much like Morph's humorous approach to his missions. However, once he was provided with videos of the content in his language, he began actively engaging in class. This shift mirrors Morph's ability to adapt and reveal his deeper, more serious side when needed. He and Beast/Hank would work on the assignments together, showcasing his ability to collaborate and contribute meaningfully to the group's success.

Bishop (Lucas Bishop) A time-traveling mutant from a dystopian future, Bishop possesses energy absorption and redirection abilities. He is a disciplined and serious warrior, determined to prevent the apocalyptic future from becoming reality. His unique perspective often challenges the team's views.

My Bishop was in the group with Rogue/Anna but could move around the class and work with other groups to gather information to bring back to his group when needed. Much like the mutant Bishop, he was not intimidated by Rogue/Anna and would challenge her about the content. He was not overbearing but would redirect the group and challenge them to think more deeply about the work, mirroring Bishop's disciplined approach and ability to offer unique perspectives that push the team to consider different angles.

Cyclops (Scott Summers) Cyclops is the X-Men's disciplined and tactical field leader. He possesses the ability to emit powerful optic blasts, which he controls through a specialized visor. A natural strategist, Cyclops is deeply committed to Professor X's dream of peaceful coexistence between humans and mutants. Though often seen as stoic and by-the-book, he struggles with the pressures of leadership and his complex relationships, particularly with Jean Grey.

Similarly, Cyclops/Scott was a strong student and independent learner. He would complete his assignments and then "help" Beast/Hank and Morph/Kevin by providing them with the answers. Much like the X-Men's Cyclops, he was more reserved than Beast and Morph but worked with them to ensure they completed their assignments. Cyclops/Scott would work diligently through tasks without being distracted by other students or class interruptions, remaining laser-focused on his work. This mirrors the X-Men's Cyclops, who stays focused on his mission and responsibilities despite the pressures he faces.

Nightcrawler (Kurt Wagner) Nightcrawler is a devout and compassionate mutant with the power of teleportation and an acrobatic fighting style. His blue, demonic appearance often contrasts with his warm, humorous personality and deep faith. Raised in a circus, Kurt's swashbuckling charm and unwavering belief in goodness make him a beloved team member who bridges the gap between humanity and mutant kind.

FCM Nightcrawler/Kurt was in the group with Rogue. He was one of the first students to notice the change in Beast's group and to seek their help during a class activity. Much like Nightcrawler's ability to see beyond appearances, he did not judge them by their previous behavior but instead acknowledged their understanding of the

content. His openness and willingness to collaborate reflect Nightcrawler's compassionate nature and his role in bridging gaps within the team.

Jean Grey Jean Grey is a powerful mutant with telepathic and telekinetic abilities, often regarded as the emotional core of the X-Men. Intelligent, compassionate, and selfless, Jean strives to use her powers to help others while fostering peace between humans and mutants. She often wrestles with her identity, balancing her humanity with the immense cosmic force of the Phoenix that resides within her. Her journey is one of self-discovery, constantly seeking balance between her humanity and the vast power she wields.

FCM Jean was an amazing math student but was very self-conscious about her English and speaking up in class. She often worked alone because of this, quietly observing her classmates and assisting other students when asked. Much like Jean Grey's struggle to balance her immense power with her humanity, FCM Jean wrestled with her self-confidence in language skills. Over the course of this study, she became more willing to participate in group discussions, reflecting Jean Grey's journey of self-discovery and integration. She and FCM Madelyne formed a kinship about the work during this study, mirroring Jean's ability to connect deeply with others despite her internal struggles.

Madelyne Pryor Madelyne Pryor is a complex character who began as a clone of Jean Grey created by Mr. Sinister. Madelyne is characterized by her fierce independence and a desire for recognition and control over her own destiny.

FCM Madelyne is very similar to FCM Jean but is not as shy. She tends to work independently but is constantly sought out by other Arabic-speaking students to explain the work. Much like Madelyne's desire for recognition and control, FCM Madelyne explains to groups of students and then reverts back to working by herself, showcasing

her independence. She occasionally works and problem-solves with FCM Jean, reflecting the complex relationship between Madelyne and Jean Grey.

Now that I have introduced you to my X-men, lets segue into the design and implementation of the flipped lessons. The flipped lessons were designed using the four pillars of flipped learning and the use of multiple representations of functions.

Study Design

Initial Framework for Flipped Classroom Design

Hamdan et al., 2013 present four key features (pillars) for flipped learning. These are flexible environments, a shift in the learning culture, intentional content, and professional educators. The flexible environment can involve physical rearrangement of the classroom space but generally refers to teachers acknowledging that a focus on students' learning may mean a variety of approaches, learning locations, and timelines. The shift in learning culture incorporates the deliberate change from a teacher-centered classroom to a student-centered approach "where in-class time is meant for exploring topics in greater depth and creating richer learning opportunities" (Hamdan et al., 2013, p. 5). Intentional content refers to the need for teachers to evaluate what content to teach directly (and when/how) and what materials students should be allowed to explore on their own. The fourth pillar recognizes that teachers are trained professionals who need to understand their students to optimize this approach and help facilitate each student's learning. Using the Four Pillars of F-L-I-P outlined by the Flipped Learning Network (2014) in conjunction with the literature on the flipped classroom model and multilingual learning in mathematics, I used the following framework for the flipped classroom design.

Pre-class Design (F-L-I)

Although there is currently no standard practice for the flipped classroom approach (de Araujo et al., 2017; Graziano & Hall, 2017; Katsa et al., 2016; Kirvan et al., 2015; Kuiper et al., 2015; Li & Li, 2022; Lo, 2017; Lo & Hew, 2017; Song & Kapur, 2017; Unal & Unal, 2017), one consistent practice is the use of instructional videos prior to class. The type and use of these videos vary but the research does provide some insight into the most effective videos for student engagement. Based on these insights, I decided that the pre-class instructional videos would be recorded in English by the teacher using screen casting software and ideally be about six minutes in duration. The literature informed my decisions to use teacher created videos (Bergman & Sams, 2012; de Araujo et al., 2017; Hamdan et al., 2013), to keep the videos around six minutes in length (Guo et al., 2014; Li & Li, 2022; Lo, 2017; Lo & Hew, 2017; Strayer et al., 2016), and to use screen casting software showing the teacher writing on a digital whiteboard (Cross et al., 2013; Li & Li, 2022; Lo, 2017; Lo & Hew, 2017). The videos also had an interactive component embedded in them because research has shown better student outcomes with the use of interactive videos for the pre-class activity (de Araujo et al., 2017; Graziano & Hall, 2017; Katsa et al., 2016; Kirvan et al., 2015; Kuiper et al., 2015; Song & Kapur, 2017; Unal & Unal, 2017). This interactive component consisted of guided notes and guided practice problems. After the teacher-created videos were recorded, I created notetaking guides by snipping images from the video and the assignments referenced in the videos. I was intentional about ensuring that the problems and vocabulary reviewed in the videos were in the same order and format on the notetaking guide. I did this because I believed it would make it easier for students to follow along with the videos and record their notes. I also explained the purpose of the videos and how to use the notetaking guides to the students prior to the first flipped lesson. The teacher informed students that he would be checking the notetaking guide as

a homework assignment since watching the videos was the homework assignment. We let students know that the videos would help them get a head start on the in-class assignment following the video homework assignment.

I used Speechify, an artificial intelligence (ai) transcription app, to transcribe and translate the teacher created videos. I used the app to translate the videos into 11 different languages. Prior to sharing the videos with the students, I vetted the videos with some of the teacher's former students fluent in the different video languages. Once the videos were vetted, I used CapCut, a video editing app, to dub over the original video for each of the translated languages. I created a OneDrive folder for the translated videos and shared them with the teacher so he could share them with the students. The teacher-created videos covered material that would normally be taught prior to students working on their own.

In-class Design (F-L-I-P)

The in-class activity connected to the pre-class activity (Li & Li, 2022; Lo, 2017; Lo et al., 2018; Lo & Hew, 2017; Strayer et al., 2016). Because the pre-class videos were designed to prime students for the in-class activities, the teacher began the class with a short mini-lesson reviewing some of the material covered in the pre-class video and connecting it to the in-class assignment. The purpose of this mini-lesson was to provide a quick review of the pre-instructional content and to provide students an opportunity to ask questions (Gariou-Papalexiou et al., 2017; Hwang & Lai, 2017; Lo, 2018). This also provided the teacher with time to explicitly connect the pre-class activities to the upcoming in-class activities (Li & Li, 2022; Lo, 2017; Lo & Hew, 2017; Strayer et al., 2016).

Algebra Concepts and Connections is one of the courses that the Georgia Department of Education (GaDOE) uses to determine the content mastery score of the school. This means that this course had a state-mandated end-of-course standardized test. Due to the high-stakes nature of this course, I designed my study around the content being taught at the time of the study. I worked closely with the teacher to create video content and select activities that aligned with both the pacing and standards of the course. Another consideration for selecting the in-class activities was the usage of multiple representations to broaden students' understanding of functions (Gagatsis et al., 2010; Leinhardt et al.; Moschkovich et al., 1993). I collaborated with the teacher to determine what activities to expose students to during the in-class component of the lesson using the GaDOE Instructional Learning Plans as a guide. These learning plans were designed to include Engage, Explore, Apply, and Reflect sections. The Engage section acts like a "hook" and provides an introduction that mentally engages students and captures their interest, provides an opportunity to communicate what they know, and allows them to connect what they know to new ideas. In the Explore section, students engage in hands-on activities to explore the new concept/big idea. During the Apply section, students apply what they have learned in a new situation to develop a deeper understanding of the big idea. The Reflect section provides students with an opportunity to review and reflect on their own learning and new understandings. Additionally, these learning plans typically integrate multiple representations of functions. This made them ideal to use for this study because they aligned with the components I wanted to incorporate in the flipped lessons. We selected tasks from the quadratics unit because that was where the teacher was in the pacing for the course. The teacher and I met to review the GaDOE

learning plans and then selected tasks based on what was going to be covered during the week. We then worked through the task to determine what material would be covered in the video. For the first video, we decided to include two problems from the Multiplying Binomials and Factoring Trinomials learning plan. For the second video, we included vocabulary from the Characteristics of Quadratic Functions learning plan. In both instances I watched the teacher-created videos and constructed the notetaking guides to accompany the videos. Students were assigned both the video and the notetaking guide for homework.

One of the key affordances of the Flipped Classroom Model is the flexible use of the learning environment to provide students with time to collaborate (de Araujo et al., 2017; Katsa et al., 2016; Kirvan et al., 2015; Kuiper et al., 2015; Lo, 2017, 2018; Lo & Hew, 2017; Song & Kapur, 2017; Unal et al., 2017). Therefore, a major component of the in-class design was to ensure that students had opportunities to collaborate. The findings from research denote class interactions as a consistent factor in a successfully flipped classroom (Fung et al., 2021; Lo, 2017; Lo & Hew, 2017). Collaborative spaces are also beneficial to multilingual learners as they provide an opportunity for students to discuss their mathematical thinking while simultaneously allowing them to practice the language in context, develop communication skills, and build confidence in expressing their thoughts (Merritt et al., 2017; Morgan, 2006; NCSM & TODOS, 2021; Schleppegrell, 2007). While students were collaborating, the teacher addressed student questions and provided immediate feedback on students' work.

Post-class Design (F-L-I)

The limited research on post-class activities agrees that some form of post-class activity is beneficial to students (Li & Li, 2022; Lo & Hew, 2017). The post-class activity helps students

consolidate their learning and provides the teacher insight into what students learned or have misconceptions about. During the last 10-15 minutes of class, the teacher did a quick assessment of student understanding by reviewing a few of the problems from the in-class assignment. Students went to the board to work problems and explain their problem-solving process. Students were also given a problem to solve independently as a ticket out the door. The components and activities of the flipped classroom used during this study are exhibited in *Figure 1*.

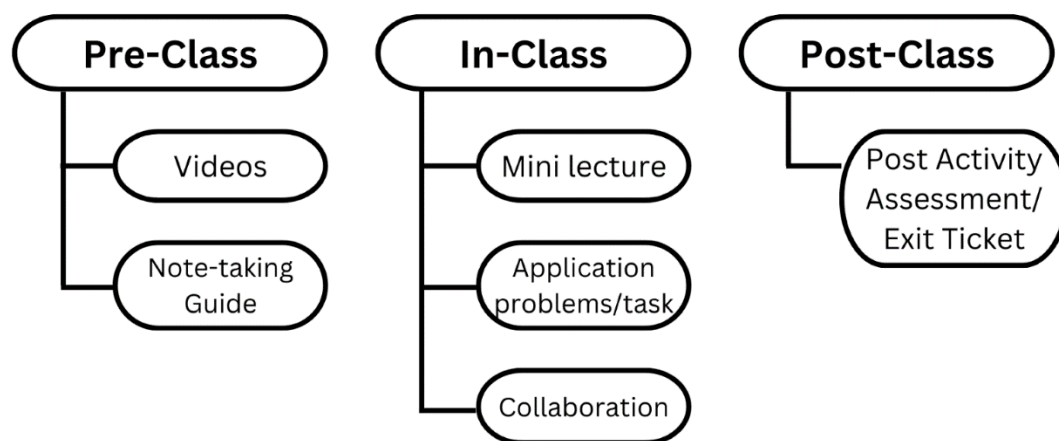


Figure 1

Components and Activities of the Flipped Classroom

Data Collection

I did a “light” design-based research model where I implemented one lesson, did some preliminary data analysis, designed the second lesson, and then did the overall analysis of the data set as illustrated in *Figure 2*.

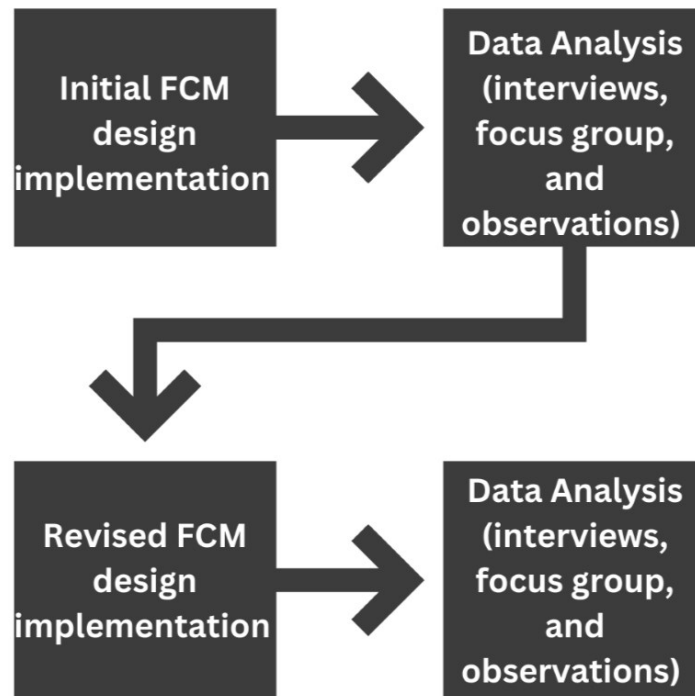


Figure 2

Schematic of the research design

Class sessions were 90 minutes on a block schedule. I conducted two 90-minute classroom observations and video recorded the class sessions during the instruction of the lessons after students were assigned videos to watch. The purpose of these video observations was to collect data on how students discussed their mathematical approach to solving problems, used the videos and notetaking guides, and collaborated after watching the videos. The videos were recorded using three Swivl¹ devices. The Swivls

¹ The Swivl is a rotating robotic mount for mobile devices and tablets. It is designed to track the accompanying “markers” (remote controls with built in microphones) and use the attached device to video record the person with the marker as they move through a room. built-in microphones), and the attached device is used.

recorded the teacher, whole class discussions, and interactions in the small groups. One Swivl was set up in the front of the classroom to follow the teacher. This Swivl captured the teacher's movements as well as the whole class discussions. The other two Swivls were placed in small groups that had focus group participants to capture the small group students' interactions and discussions. The Swivl camera set ups are shown in *Figure 3* and *Figure 4*.

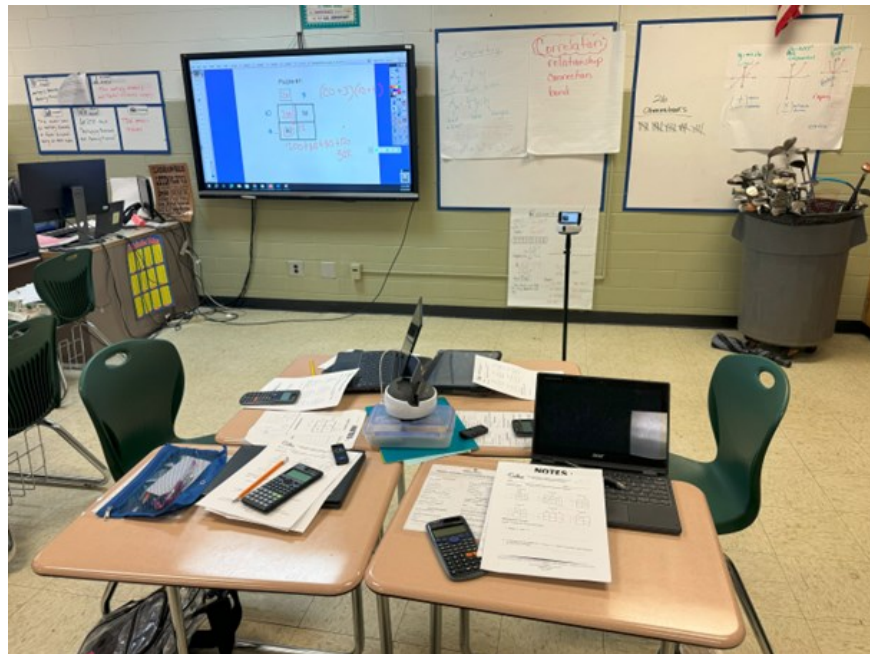


Figure 3

Camera set up for whole group and small group classroom observation

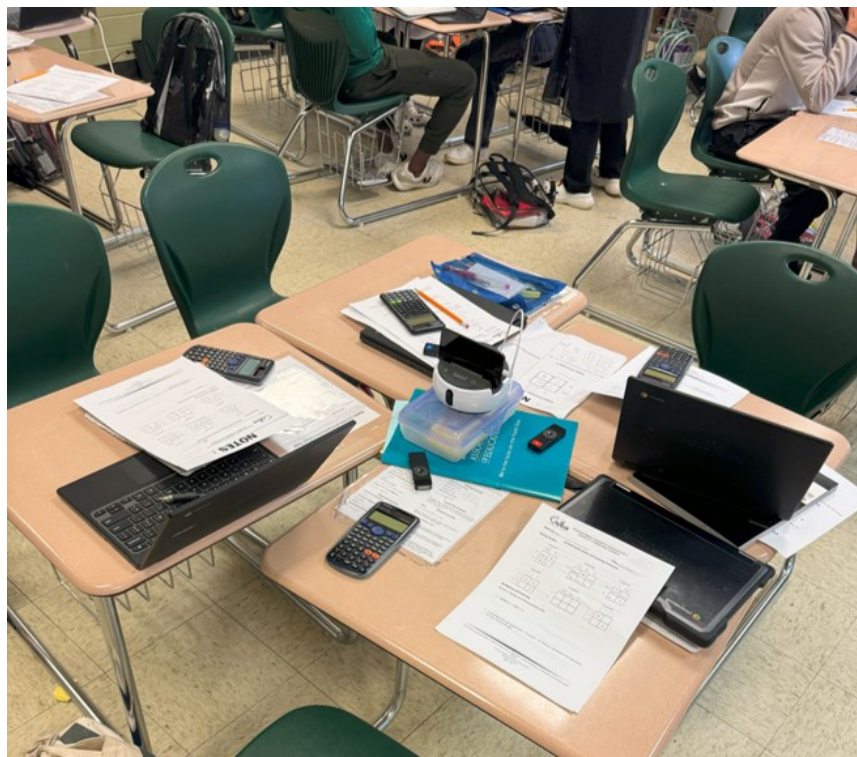


Figure 4

Camera set up for focus group observation

I video-recorded the in-class interactions involving the selected groups of students. The video recordings were used to capture both verbal and non-verbal student-student and student-teacher interactions. I also took field notes and made research memos while observing the class and the different student groups as they completed the tasks. I interviewed the teacher about his noticings and/or perceptions about student engagement in mathematical discussions after students viewed the videos. I also interviewed selected students. These selected students participated in individual interviews and a focus group to assess their perceptions of the video and the flipped lesson. Students were also asked to provide feedback on what they liked/disliked about the videos as well as suggestions for

future video creations. Specific details about these methods of data collection are in the next section.

Data Collection Methods

I triangulated data collected from classroom video observations, teacher interviews, student interviews, and student focus group interviews. All of the interviews were semi-structured and used an interview guide to help “make interviewing a number of different people more systematic and comprehensive by delimiting in advance the issues to be explored” (Patton, 2015, p. 439) as well as to provide “topics or subject areas within which the interviewer is free to explore, probe, and ask questions that will elucidate and illuminate that particular subject” (p. 439).

Video observations. I conducted one video observation for each flipped classroom activity implemented. Each observation lasted for 90 minutes and captured an entire block period to provide a fuller understanding of the context and environment that students were participating in after watching the video.

Broadly stated, I was interested in analyzing the linkages between the students’ discussions and the videos. Observation allowed me to view “the world in terms of people, situations, events and the processes that connect these” (Maxwell, 2013, p. 29). Observations also permitted me to “see things that may routinely escape awareness among the people in the setting” (Patton, 2015, p. 333). My objective in these observations was to witness these “things” and to see the various nuances and interactions that play out in a classroom setting.

Semi-structured Individual Interviews. I conducted three individual teacher and student interviews throughout the course of the study. The initial interview was

conducted prior to the introduction of the video lessons and the protocols can be found in Appendices A and B. The initial interview served as baseline data for the study and provided an opportunity for me to build more of a rapport with the student participants. The second interview occurred after the first flipped video lesson on the same day as the flipped lesson and the third interview occurred after the second flipped video lesson on the same day as the second flipped lesson. Some of the interview questions for the second and third interviews were based on hypotheses and initial findings from previous interviews and interactions with participants. The primary purpose of the interviews was to obtain data on the teacher's and students' perception of the usefulness of the lesson videos in assisting students with understanding the content and engaging in classroom activities, thereby providing insight into my primary research question: *1) What are effective strategies for designing flipped mathematics classroom materials that cater to the diverse language backgrounds of multilingual students?* The student interviews also addressed my research questions two and three: *2) How do multilingual learners use videos provided in their native/home language as part of a flipped classroom?* *3) How do multilingual learners perceive the use of mathematics videos in their native/home language as part of a flipped classroom approach?* I asked questions about participants' experiences with the flipped videos, notetaking guide, and in-class activities. Full interview protocols can be found in Appendices A, B, C, and D.

Semi-structured Focus Group Interviews. There were two focus group interviews. The focus group was comprised of 5 students who had access to lesson videos in their native language. The interviews consisted of an interview after the first flipped video lesson and an interview after the second flipped video lesson. I wanted to

interview the students in a group because “talking with them as a collective” (Johnson-Baily, 2004, p.126) gives them power. The purpose of the focus group interviews was to provide the students’ perspective on the usefulness of the video lesson in assisting them with understanding the content. The focus group questions were based on things that arose from the classroom observation videos, individual interviews, and the content covered in the unit. These interviews addressed my research questions:

1. What are effective strategies for designing flipped mathematics classroom materials that cater to the diverse language backgrounds of multilingual students?
2. How do multilingual learners use videos provided in their native/home language as part of a flipped classroom?
3. How do multilingual learners perceive the use of mathematics videos in their native/home language as part of a flipped classroom approach?

The full focus group protocol can be found in Appendix E. The summary of the students’ participation in the individual interviews and focus interviews as well as their in class small group can be found in *Table 2*.

Data Analysis

Upon initial analysis, I wanted to determine linkages that could be established by comparing and contrasting, identifying underlying associations, inference, and discovering connections and confirming relationships among individuals as well as classes of constructs (LeCompte & Preissle, 1993). Therefore, I used thematic analysis to determine the main overarching themes for the case (the classroom).

Because I used observations and interviews over a period of time during this study, I also used constant comparison because it “combines inductive category coding with simultaneous comparison of all social incidents observed and coded” (LeCompte & Preissle, 1993, p. 256). Therefore, as social phenomena were recorded and classified, they were also compared across categories (p. 256). This type of analysis allowed me to answer questions that arose from the analysis of and reflection on previous data.

To begin my analysis process, I first analyzed each individual data source and then conducted a cross-source analysis. I used the constant comparative method decoupled from grounded theory (Glaser & Strauss, 1967) to analyze the data. First, I identified initial codes in each of the data sources based on my own observations and field notes. For instance, during the classroom observations I noticed codes pertaining to student understanding of the content vocabulary, student collaboration, and participants’ reference to the videos. During the focus group interviews the codes thoughts about video helpfulness, suggested revisions, and components of the videos students liked/disliked emerged. In the student interviews I noticed codes of frequency of video usage, thoughts about translated video helpfulness, and excitement about having access to videos in multiple languages. Following the implementation of the initial FCM design I used these findings to revise the video design for the second flipped lesson. I then employed open coding (Strauss & Corbin, 1990) to identify specific pieces of content and assigned labels (codes) to them. Using my research questions as the lens to analyze these specific instances, I began to generate themes to categorize these codes. I continued reviewing my themes, collapsing and renaming them until I finally settled on the themes that I will discuss in the next chapter.

After the open coding, I applied axial coding (Strauss & Corbin, 1990) to code each data source based on the initial themes. I further refined these themes by collapsing codes and creating sub-themes. I then analyzed across the data sources to look for differences and similarities in the themes. I have provided a more in-depth explanation of this process below.

Focus group and individual interview data. I fully transcribed each interview verbatim using the transcription feature in Word. After transcription I uploaded the transcripts to NVivo and employed open coding (Strauss & Corbin, 1990), to generate codes that characterized the students' use of the videos based on my initial pass through the data. For example, after the first flipped lesson I looked for instances where the participants mentioned what they liked, disliked, and wanted changed/modified so I could revise the videos for the next lesson. In addition to specifically looking for instances of these codes, I also identified specific pieces of content that seemed germane to my research interests. As I coded, I highlighted relevant passages from the transcripts to illustrate the codes. Then, using axial coding (Strauss & Corbin), I went through the transcriptions several more times to create themes related to my research questions. Finally, I cross-analyzed the interviews of a single participant and then cross-analyzed the interviews of all the participants and the focus group to compare the ideas that were produced during my analysis of each interview.

Classroom observations. I partially transcribed episodes from the classroom observation into a lesson graph (Izsák, 2008) using Microsoft Word. I used these lesson graphs to organize the data into episodes determined by the content of the flipped video and the mathematical lesson. Examples of episodes include a whole-class discussion of

one problem and a conversation between the teacher and a student(s) during group or individual work. The lesson graph included the start and end times of each episode, a brief description of what was being discussed, and key comments made by the teacher and students. These lesson graphs were analyzed to create codes that characterized the students' use of the videos and were compared to the interview transcriptions. The research questions, data sources, and analysis methods are summarized in *Table 3*.

Table 3

Research questions and corresponding data analysis

Research Question	Data Sources	Analysis Methods
What are effective strategies for designing flipped mathematics classroom videos that cater to the diverse language backgrounds of multilingual students?	• Classroom observations • Small group observations • Student focus groups • Student interviews • Teacher interviews • Field notes	I analyzed the interviews of a single participant and then cross-analyzed the interviews of all the participants and the focus group to compare the ideas that were produced during my analysis of each interview. This was then compared to the analysis of the classroom observations and field notes to determine which parts of the FC design were effective for multilingual students.
How do multilingual learners use videos provided in their native/home language as part of a flipped classroom?	• Classroom observations • Small group observations • Student focus groups • Student interviews • Teacher interviews	I analyzed the interviews of a single participant and then cross-analyzed the interviews of all the participants and the focus group to compare the ideas that were produced during my analysis of each interview. This was then compared to the analysis of the classroom observations and field notes to determine how multilingual learners used the videos.

How do multilingual learners perceive the use of mathematics videos in their native/home language as part of a flipped classroom approach?	• Classroom observations • Student focus groups • Student interviews • Teacher interviews	I analyzed the interviews of a single participant and then cross-analyzed the interviews of all the participants and the focus group to compare the ideas that were produced during my analysis of each interview to determine how multilingual learners perceived the use of the videos.
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CHAPTER 4

FINDINGS

Prior to the flipped lesson the classroom was already organized in small groups, with desks arranged to accommodate four individuals each. However, not all groups were full; some had only two or three members. This arrangement was meant to foster collaboration, but the reality was more complex. Although the students appeared comfortable with one another and with their teacher, their interactions within their groups revealed layers of social dynamics, linguistic barriers, and varied levels of engagement with the subject matter.

The teacher, who I refer to as Professor X, typically stood at the board, guiding the class through the day's mathematics lesson. He alternated between explaining concepts, solving problems, and fielding a steady stream of student questions. His presence was a central focus, as students frequently sought his guidance rather than turning to their peers for assistance. The questions they asked him often revolved around clarifications of English terms rather than the deeper mathematical concepts, leaving little opportunity for the teacher and students to explore the material in depth.

The classroom reflected the diversity of its students, with language playing a significant role in how they organized themselves. Students who spoke the same language often gravitated toward one another, forming clusters of Arabic speakers, Pashto, and Urdu. Urdu speakers mostly in Pashto or Urdu, laughing and socializing more than engaging with the lesson. They occasionally copied problems from the board but showed little

understanding or effort to work independently. The Burmese students, though quieter, were similarly disengaged from collaborative problem-solving, with most choosing to work individually or passively follow the lead of a stronger student.

Meanwhile, students who did not share a common language with any of their classmates were scattered across the classroom. Most of these students listened attentively to Professor X and made efforts to complete their assignments, but they, too, rarely collaborated or asked peers for help. Their participation was steady but solitary, adding to the classroom's overall pattern of isolated effort rather than collective problem-solving.

Two groups of students were selected for closer observations for the study. Focus Group 1 consisted of five students with different language backgrounds. Raven, an Afghani girl raised in Germany, spoke multiple languages but preferred German. She would alternate between sitting in the group and sitting at one of the desks along the side of the room so she could work independently. Emma and Remy, both Burmese students, would occasionally ask one another questions about the work but they mainly listened to the teacher and took notes. Ororo, a Tanzanian student whose home language is a dialect of Swahili, also primarily listened to the teacher and took notes. Jubilee, a female Eritrean student whose home language is Tigrinya also primarily listened to the teacher and took notes, but she would also openly ask her fellow classmates questions. The group sat together but the students worked independently and there was little to no collaboration.

Focus Group 2, comprised of Afghani boys, stood out for their initial lack of engagement in lesson activities. Their chatter was lively but unrelated to the lesson, and

their occasional forays into notetaking seemed perfunctory. One strong student in this group consistently completed the work, which the others appeared to copy without attempting to understand or replicate his process. Collaboration in this group was minimal, and their learning appeared to stagnate as a result. When I was initially selecting groups for this study, Professor X discouraged me from choosing this group to observe. He believed the group would not yield significant data because he said they didn't participate and "goofed off" during class. I argued that they would be perfect for the study because if they engaged after watching the videos it would provide a strong case to use videos in students' languages in the future. As the study progressed, it became apparent that this group of students benefited from the use of the videos and Hank will be highlighted throughout this chapter.

Other notable figures in the classroom included Anna, Madelyne, and Jean. Anna, a Burmese female student, emerged as a dominant force in her group. She led discussions, often unchallenged by her peers, who relied on her to guide them through the assignments. Her group members participated but seldom questioned her or contributed new ideas. In contrast, two other strong female students, Madelyne, an Arabic speaker, and Jean, a Vietnamese student, preferred to work independently. Both excelled in mathematics but approached their work differently. Madelyne was open to assisting her peers when asked, while Jean, self-conscious about her English, avoided peer interaction and worked quietly on her own.

The linguistic diversity of the classroom presented both challenges and opportunities. Although some students helped one another with translations of English terms, these interactions rarely extended to deeper discussions about the math content.

The emphasis on getting correct answers overshadowed the process of understanding how to arrive at those answers. This focus on correctness seemed to permeate all groups, reinforcing a reliance on stronger students and the teacher, rather than fostering an environment of shared learning and critical thinking.

Despite the challenges, the classroom was not without its moments of connection. Emma and Remy, who both spoke Zo, occasionally exchanged ideas and supported each other. Madelyne was a willing helper when her Arabic-speaking peers sought her out. However, these interactions were exceptions to the broader pattern of fragmented and uneven engagement.

In this microcosm of linguistic and cultural diversity, the classroom thrived on the energy and resilience of its students but struggled to fully harness the potential of collaborative learning. The teacher's efforts to manage the diverse needs of the class underscored the complexity of fostering inclusion and academic growth in such a multifaceted environment. While some students thrived in their independence or as leaders within their groups, others remained on the periphery, their engagement hindered by language barriers, social dynamics, or personal preferences.

Design of Video 1

I met with Professor X prior to deciding on the topic and content for the flipped lesson. We looked at the Georgia Department of Education (GaDOE) instructional learning plans in Unit 4: Modeling and Analyzing Quadratic Functions. After reviewing the learning plans in the unit, we chose Multiplying Binomials and Factoring Trinomials (see Appendix F) because it aligned with Professor X's instructional goals for the week of the flipped lesson. This activity also provided students with an opportunity to engage

with multiple representations of factoring which, based on the research highlighted in Chapter 2, positively impacts learning outcomes for ML students. After the task was selected, we discussed what would be included in the instructional video for the lesson. We selected two problems from the task to use as examples for the instructional video. We chose two problems because this is how many problems Professor X could explain within the 6-minute video length goal based on the optimal video length from research (Guo et al., 2014; Li & Li, 2022; Lo, 2017; Lo & Hew, 2017; Strayer et al., 2016). The problems chosen were Puzzle #3 (area model) and Section 2 #2 from Multiplying Binomials and Factoring Trinomials because they were mid-level difficulty problems and provided examples for the type of problems students worked on in each section of the activity. After the problems were selected, Professor X recorded himself working the problems using screen casting software (Cross et al., 2013; Li & Li, 2022; Lo, 2017; Lo & Hew, 2017). Based on recommendations for best practice in the literature, I decided to create a notetaking guide (de Araujo et al., 2017; Graziano & Hall, 2017; Katsa et al., 2016; Kirvan et al., 2015; Kuiper et al., 2015; Song & Kapur, 2017; Unal & Unal, 2017). I created the notetaking guide (*Figure 5*) for the video using the same examples Professor X worked in the video so students could work the problems along with him while they watched the video. I also added a column with a section for “Words I don’t know” and a section for “Questions that I have”.

NOTES :

Video Example 1

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Video Example 2

What are the factors of the trinomial $x^2 + 7x - 18$?

Figure 5

Video 1 Notetaking Guide

Classroom Engagement Following Video 1

After watching the flipped video and using the notetaking guide the energy in the classroom was noticeably different as students engaged with the day's lesson. Students were excited to have videos available in multiple languages, including English. This

novelty captivated the students, drawing them into the material. Many reported watching the videos multiple times, experimenting with different language versions to deepen their understanding. Their enthusiasm was palpable, translating into increased effort and participation. For the first flipped lesson, most students entered the classroom with their notetaking guides completed, having diligently jotted down sample problems and vocabulary while watching the videos.

At first, members of Focus Group 1 worked quietly and independently, relying on their notes to tackle the assignment. However, after lunch, a shift occurred. Emma and Ororo replayed the video in English, sparking a group-wide discussion as they sought to align their understanding of the problems. Remy, who had a strong grasp of the material after watching the videos, became an anchor for the group. He shared his notes and began explaining concepts to his peers. For example, when Raven struggled with a specific problem, she asked Remy a targeted question about how to use the area model. Many students did not completely grasp the concept of factors being a part of a whole. Students were placing factors in the boxes but did not comprehend the need to add the boxes together to arrive at the final answer. Remy explained this process to Raven.

Raven: Add this together?

Remy: Add all of it

Raven: Huh?

Remy: Like this, just add it all up. That's it. (Using his paper to guide her through the problem) $2000 + 600 + 40 + 200 + 60 + 4$ that's going to give you

2904

Remy calmly walked her through the steps, referencing both the video and his notes to guide her. His ability to articulate the solution not only helped Raven but also solidified his role as a peer leader.

Focus Group 2, typically known for its lack of engagement, showed a remarkable transformation. Hank, one of the group members, had watched the video in both Pashto and Urdu. Impressed by the translations, he convinced his group to do the same in Urdu, their shared language. His enthusiasm was contagious, and soon the entire group was actively working on the assignment, something they had rarely done before. For the first time this school year, they didn't rely on a single student to complete the work; instead, they collaborated, asked questions, and sought guidance from the teacher and others in the classroom.

As I walked around to the different groups, I noticed the word trinomial written on several notetaking guides under "words I don't know". I also noticed students did not know what the word factor meant. When the teacher asked the class for the factors of 322 using the area model the students stared at him blankly before trying to respond to his question. The teacher proceeded to work the example with a few students answering his questions.

Professor X: 322 is that entire area, right? OK, what are the factors of 322? So make sure we get those words down.²

A student says 322 is the area.

Professor X: OK, you're not wrong about that, but what factors did we use to get there?

² Duplicate words have been removed from the transcripts to make them easier to read. The original meaning of the transcripts have not been altered.

A student says 10.

Professor X: OK, 10. OK, you're on it. You're on it. It's somewhere on my board right here. What your factors are.

A student says 80.

Professor X: OK, 80 is not a factor, OK.OK. Yeah. Yeah. What? What is being multiplied together to get the 322?

A student says, "it's 10".

Professor X: OK. Yeah. Yes, you're not wrong with that. I'm going to write. If I wrote 23 and 14 are y'all OK with that?

Class says yes.

Professor X: Yes, my factors of 322 would be $23 * 14$ or $(20 + 3) * (10 + 4)$.

Right, right. My factors of 322 that entire area is right here $(10 + 4) * (20 + 3)$ y'all OK with that?

After multiple instances of students asking the meaning of various content vocabulary, I approached the teacher to discuss my noticings and ask if I could teach for a moment. During a brief mini-lesson on vocabulary terms like *trinomial* and *factor*, the students listened intently, eager to master the language and concepts they needed to solve the problems.

Jean and Madelyne, known for their preference for working alone, continued to excel independently. However, their independence didn't preclude them from helping others. Jean assisted members of Group 3 with difficult problems, clarifying steps and ensuring they understood the process. Madelyne, meanwhile, explained the assignment in

Arabic to a group of boys who struggled with the English instructions. Her assistance enabled the group to complete their work.

In Student Group 3, Anna maintained her usual leadership role. After Jean provided initial clarifications, Anna took over, guiding her peers through the assignment. The group worked steadily, asking questions and building on one another's ideas. Anna's confidence and vocal participation during the mini-lesson on vocabulary set an example for others, reinforcing her influence within the group.

The introduction of multilingual videos and the subsequent vocabulary mini-lesson marked a turning point for the entire class. During the lesson, students like Anna and Remy eagerly contributed, while Jean corrected a mistake on the board, demonstrating her understanding of the material and an increase in speaking confidence. Hank's excitement about the videos momentarily distracted him as he tried to replay one during the mini-lesson, but he quickly refocused once redirected by Professor X. After clarifying the key terms, the class dove back into their assignments with a newfound confidence.

The atmosphere was charged with focus and collaboration. Students who had been absent relied on their classmates' notes to catch up, while others replayed the videos repeatedly, using them as a guide to work through problems. The classroom buzzed with quiet conversations as students shared strategies, explained solutions, and refined their answers together. For once, the teacher's role shifted from being the sole source of knowledge to a facilitator of a more collaborative and self-directed learning process. This day's lesson demonstrated the power of accessibility and language inclusivity in fostering engagement. The students, armed with their videos, notetaking guides, and each

other, showed not only an improved understanding of the material but also a stronger sense of agency in their learning.

Student Reactions to Video 1

I conducted student interviews with four students and focus group interviews on the same day as the flipped lesson. Based on their responses in student interviews and the focus group interview, students liked: the videos being in their native language, the length of the video, their teacher explaining in the video, the explanations of the sample problems, and the notetaking guide.

Videos in their native languages

During his student interview, Hank responded to my question about which language he watched the video in by saying, “He helped me explaining. Yeah in Pashto my home language. And I’m understand clearly.” I hypothesized that watching the videos impacted his class participation, so I asked him about it during the interview.

Int: And has watching the video made you want to work on problems more in class? Has it helped you want to actually do your work in class more?

Hank: Yes, yes, it’s work me.

Int: Why do you think that? Why so?

Hank: Because my language and I’m understanding clearly.

Another student, Remy, talked about the advantages of having the videos in their own language, “They can learn from their own language using the AI translation, which is better for them.”

Overall, during the first interviews and focus groups, most students mentioned the importance of the videos being in their own language. The students who did not mention

the importance of the videos being in their own language were students who spoke a dialect of a language that I could not provide a translation for, so they listened to the English video and/or a language close to their home language. For instance, the Burmese students listened to English or Burmese, but their home language was Tamil or Chin.

Length of video

During their interviews, some students mentioned they watched the video more than once. Hank watched “the whole video three to four times. I’m one time I’m watching in the class and two time I’m watching at home.” Emma said she paused and rewound the video about three times. When directly asked about video length during classroom observation, Jean said it was “good” and Raven said it was “OK.” Anna’s group gave a “thumbs up” when asked the same question. The short length of the video likely contributed to the ability to watch the video more than once. This correlates with the literature that states the videos should be under 10_-minutes long to promote optimal viewing (Guo et al., 2014; Li & Li, 2022; Lo, 2017; Lo & Hew, 2017; Strayer et al., 2016).

Their teacher explaining in the video

When asked what he liked about the video, Remy said “the voice” referring to Professor X’s voice. Emma also stated that she liked “that the teacher explain and like talk about the math a lot. It’s like good thing.” All students in the focus group said they liked having their teacher explaining in the video.

Explanations of sample problems

In his student interview, Remy indicated that he liked Professor X explaining the sample problems by saying “Yeah, he shows what is his steps of solving and which you

know solution is needed to be put in order to solve the answers.” During the focus group interview when Ororo shared that she liked the explanations of the sample problems the other students agreed with her sentiment.

Int: What did you think was helpful about the video?

Ororo: Step by step. (the other students nodded in agreement)

Int: The step-by-step process or doing the example?

Ororo: Yeah. And then I got to the answer.

Hank: Yeah

Remy: The same answer

Int: Step by step so y'all think it's good that if we do the video, we do examples in the videos? That's what you find helpful? (students nod their heads in affirmation)

Emma: Same.

Overall, during the first interviews and focus groups, all the students agreed that the explanation of sample problems was helpful.

Notetaking guide

Students stated they found the notetaking guide helpful because it helped them remember what was covered in the video and they used it during the class activity to complete their work. During her student interview, Emma shared that the notetaking guide helped her remember information.

Int: Did you take notes while you watched the video?

Emma: Yeah I did

Int: And did you use those notes to help you with the problems?

Emma: Mhmm. At first I forgot everything like, I can't find it that's why I'm writing down everything.

When I posed the same question to Hank during his student interview, he smiled and nodded yes before saying “Yes, today. I give you one answer. My name, my note. I was just reading.”

In both the student interviews and the focus group interview, all the students stated they found the notetaking guide helpful and used it during class to complete their assignment.

Teacher/Researcher Observations Related to Video 1

I also interviewed the teacher and shared my noticings with him after his interview. During the interview the teacher stated that he believed the students were more engaged during class because they had access to the videos.

Professor X: I think third block was focused like more focused today because of it. And it was like, you know I think you have like a video recording and whatnot. And the kids were like, oh, OK. I'm focused.

Additionally, the teacher stated that “having a video with the math explained. And, you know, I think it could have miracles”. He also noted the advantages of “having it in their language. Where they can specifically know exactly what's going on and there's, you know, language isn't the reason to hold them back. I do think there there's benefits.”

There were a few students who were reluctant to participate in the student interviews and focus groups because they were self-conscious about speaking in English, but they were willing to interact with me during class. One was a female Vietnamese student (Jean), who said the Vietnamese version of the lesson was helpful. Another was a female Arabic

student (. Madelyne) who shared the same sentiment for the Arabic video. There was a group of Arabic boys rewatching the Arabic version of the video as they worked on the in-class assignment. Ororo and Emma rewatched the video during class. They used Professor X's explanation of a problem to assist them with the in-class activity. Multiple students in the class were rewatching the video to hear Professor X's explanation of a problem; this continued throughout the entire class period.

Throughout the class period students were referring to their notetaking guides while they worked on the in-class assignment. Ororo used her notetaking guide to explain a problem to Emma. Hank used his notetaking guide to show his group that a problem was worked during the flipped video. Remy used his notetaking guide to explain a problem to Raven and Ororo.

Remy: Need help?

Ororo: Yeah, I need help on this one right here

Remy: You know, they get $3x^2$ -. What do you need to put in these two boxes?

You're missing, this one missing one thing and this one missing one thing.

Raven: How are you getting $3x^2$ -?

Ororo: That would be 3.

Remy: How do you get x?

Ororo: Three times two?

Remy: Look. See like this like this. (He refers to his notetaking guide, *see Figure*

6)

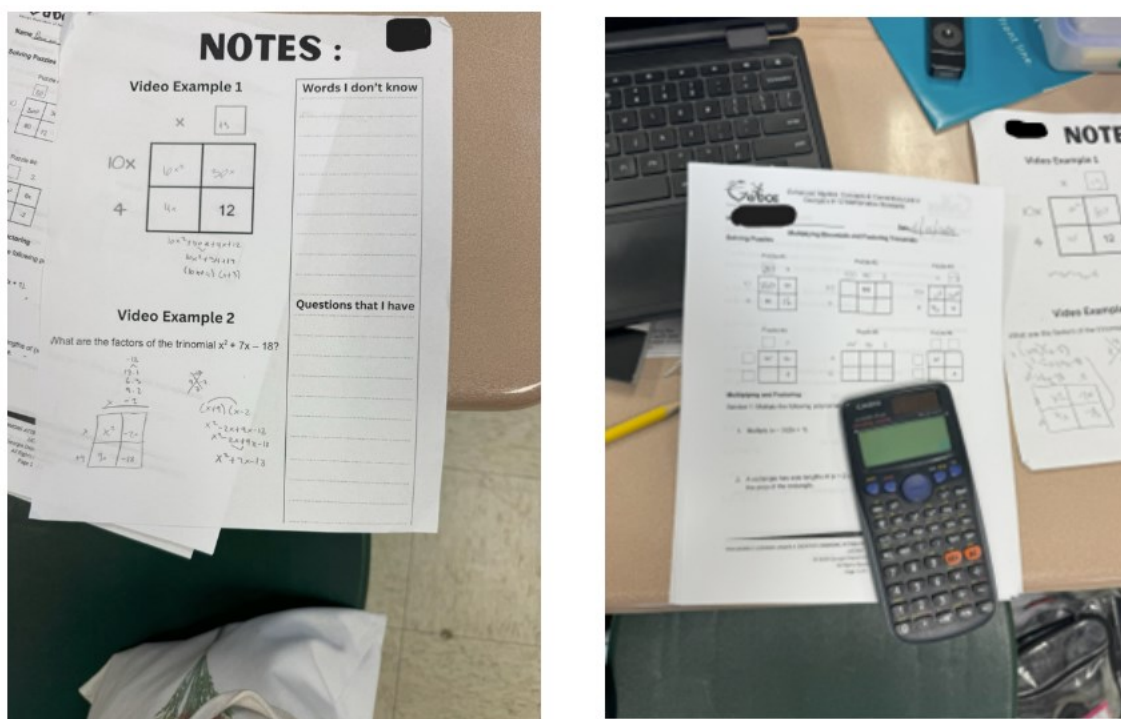


Figure 6

Students' notetaking guides being referenced while students worked on the class assignment

As I walked around the room, I noticed most of the students rewatching the videos in their home languages and using the notetaking guide to assist them with the assignment. Several students had the word trinomial written in the section of the notetaking guide for “words I don’t know” (*Figure 7*). Both the teacher and I noticed students asking questions about other words such as factor, binomial, and term. For instance, when I worked with Focus Group 2, the students were having difficulty with understanding what the assignment was asking for, so I asked them if they knew the word “factor.” The students shook their heads to indicate they did not know the word or its meaning. These questions were prevalent enough to prompt us to stop the activity and

conduct a mini lesson on the vocabulary. After the vocabulary mini lesson, students were able to continue working on the assignment with minimal support from us.

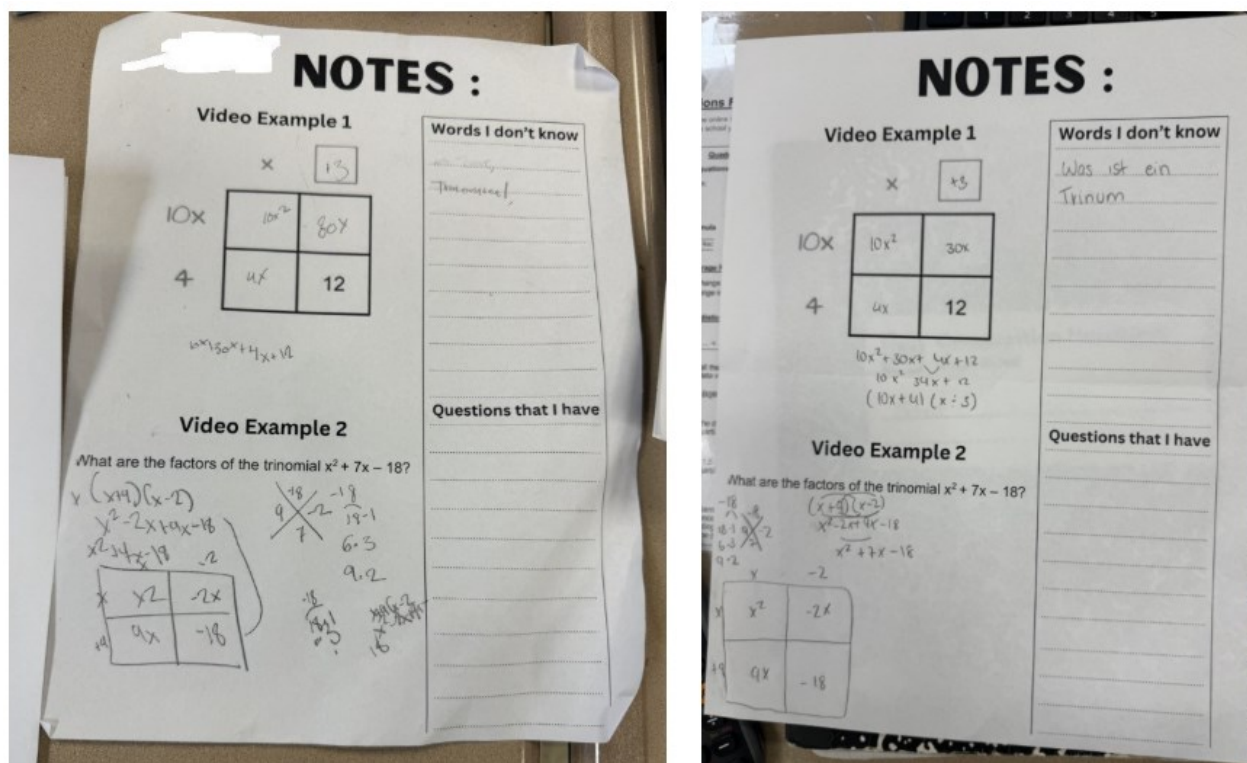


Figure 7

Students' notetaking guides with trinomial as a word they don't know

Revisions Needed

I used the information gathered in the interviews along with my noticings to begin designing the second flipped lesson. Based on the feedback from the students, focus groups, and teacher along with my memos and observation notes, I determined that the students would benefit from having a video with more vocabulary front loading. I also discovered that the teacher was really concerned about keeping the video around 5 minutes because during our first flipped lesson planning meeting I shared with him that

research states the ideal time for an instructional video is around six minutes. I told him it would be OK if the video was longer as long as we stayed under ten minutes because the literature states that videos longer than 10 minutes lose the interest of the viewer (Guo et al., 2014; Li & Li, 2022; Lo, 2017; Lo & Hew, 2017; Strayer et al., 2016). When asked about the videos during the interviews the students stated that the videos were “perfect” and wanted us to provide more videos for future lessons.

Design of Video 2

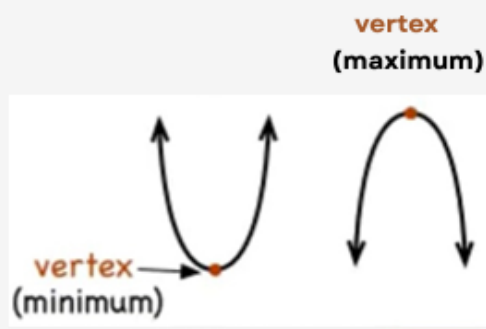
I met with Professor X once again to decide on the topic and content for the second flipped lesson. We looked at the GaDOE learning plans for Unit 4 and selected Characteristics of Quadratic Functions. We chose this task because it encompassed a lot of vocabulary and it applied the vocabulary to real world scenarios. This activity also required students to analyze and discuss multiple representations of quadratic functions. Therefore, it provided an opportunity for us to reinforce vocabulary and simultaneously check for conceptual understanding. The second flipped video was 8-minutes and 29-seconds long. The video focused on vocabulary words that students would encounter in the in-class assignment. We included images of parabolas with the components of a quadratic function labeled and included the following words with accompanying visuals: vertex, maximum, minimum, x and y-intercepts, axis of symmetry, intervals of increasing and decreasing, domain and range. I created a notetaking guide to accompany the video. To create the notetaking guide (*Figure 8 & 9*), I took snippets of the images from the

instructional video and included fill in the blank definition sentence frames for students to complete while they watched the video.

QUADRATIC VOCABULARY

Fill in the blanks while you watch the video.

The _____ of a parabola is the maximum or minimum of a parabola. It is the point on a parabola that intersects the axis of symmetry.



The _____ (or zeros) of a function are the point(s) where the function crosses or touches the x-axis, or where $y = 0$.

The _____ is the point that crosses the y-axis.

The _____ is a vertical line that passes through the vertex and divides the parabola in half.

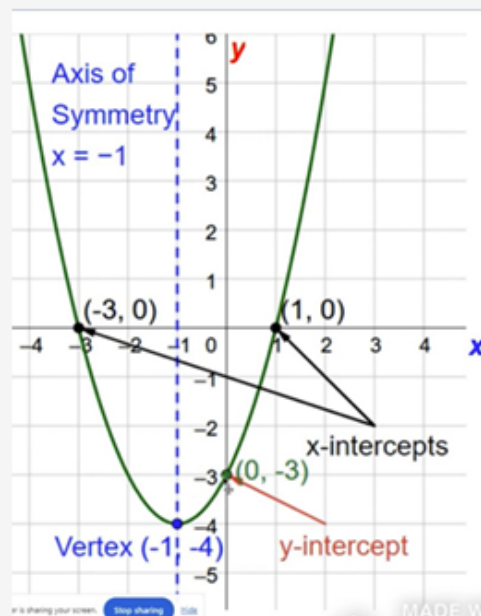


Figure 8

Classroom Engagement Following Video 2

The second flipped lesson garnered a great deal of excitement from the students and the teacher. Students dove into their work with an unprecedented level of enthusiasm. Professor X enthusiastically shared with me that students from all his classes had been eagerly asking for access to the videos even before the lesson began.

Professor X: Like I said, I had kids coming in the morning. It was like hey, I don't have access to it. You know where is the video? Where where's going on it or I missed and you know, I was like, oh, heck yeah, please, you know.

Researcher: Are these kids who normally try to get their work, or is that like a? Did you have some different personalities trying to get, they wanted to have access?

Professor X: It was different. It was different.

He detailed that his first and second-period classes, traditionally the less engaged and composed of students with the lowest English proficiency scores, had also experienced a dramatic transformation. They had embraced the assignment with excitement, completing the tasks and working collaboratively.

Professor X : Even like to engage and try in the lessons like first and second block, I definitely had students who normally like zone out and whatnot and they engaged in the lessons it's definitely a positive thing.

In the third block, the class I was observing for the study, the atmosphere was equally extraordinary. Every group, without exception, was fully engaged. The usual classroom dynamics had shifted, dominant voices were no longer overpowering the discussions. Instead, group conversations flowed naturally, with each student contributing

to the task at hand. They debated, questioned, and supported one another as they worked through the assignment. For example, Anna, known for her dominating presence, found herself in an unfamiliar position. The group was tackling the concept of maximum and minimum, and Anna's interpretation sparked a heated debate. She confused the terms maximum and minimum. She understood the concept but switched the English definitions of the words. Unlike in the past, her group members didn't simply accept her answer without question. They stood their ground, explaining their reasoning and pointing out why they believed her understanding was incorrect. Their confidence was palpable, and they refused to back down until the matter was resolved. Eventually, they called me over to settle the debate.

Anna: It's MAXIMUM (pointing at her groupmate's paper indicating that he needs to change his answer)

Bishop: No (and shakes his head)

Anna: It's MAXIMUM (even louder trying to get him to change his response)

Bishop: No (shakes his head and throws up his hand)

Me: Wait, Anna. Say it again. The lowest point?

Anna: This is the maximum. It is the lowest point (she points to the picture on her paper) on the graph.

Me: Lowest is minimum (I use my hand to demonstrate lowest)

Bishop: See (and smiles)

Anna: Wait what?!

Bishop and Kurt laugh.

Anna: No, lowest is maximum.

Me: Lowest is minimum (I point to the minimum on her paper). Maximum is highest (I point to maximum on her paper).

Kurt: Do you understand?

Anna: I do understand (the entire group laughs)

When Anna realized her group was correct, she smiled sheepishly and then laughed with them. Once everyone in the group had a clear understanding of maximum and minimum they continued working on the assignment.

Focus Group 2, typically reliant on one dominant student to complete the work, showed a remarkable transformation. Hank and Kevin led the charge, working through the assignment independently and correctly. Switching fluidly between English and Urdu, they helped one another refine their answers, offering corrections and clear explanations when something was wrong. For the first time, they didn't seek out the teacher for assistance but relied on each other instead. Recall, Professor X discouraged me from using this group because he did not think the students in this group would complete the assignments or participate in the class discussions. However, with the implementation of the FCM and the translated videos this group was not only able to complete the assignment, but they clearly understood the content and were fully engaged in the lesson. Professor X marveled at their progress, admitting that he had never seen this level of focus or collaboration from the group before.

In Focus Group 1, Ororo's excitement was infectious. She bounced in her seat, her face glowing with pride as she explained the material to her group members. The joy of understanding and the thrill of being able to teach it to others had her smiling from ear to ear. Her group, inspired by her enthusiasm, engaged deeply with the assignment,

asking questions and sharing insights. For Ororo, this was a breakthrough moment, a time when her confidence and comprehension aligned, allowing her to take a leading role in her group.

Even Jean and Madelyne, who usually preferred working alone, showed a willingness to engage with their peers. Jean, always methodical and focused, was more open to discussing the work with others, offering clarifications when needed. Madelyne, too, stepped out of her usual solitary approach, engaging with classmates in brief but meaningful conversations about the assignment. Their independence remained a strength, but their willingness to connect with others added a new dimension to the collaborative spirit of the class.

The entire class was deeply immersed in the assignment. Students who had previously been disengaged or dependent on the teacher for answers were now seeking help from one another. Conversations revolved around the content rather than English vocabulary, a stark departure from the norm. The notetaking guides and videos had empowered students to come prepared, and their readiness was evident in their questions, which were now more content-driven. For instance, during the card sort portion of the activity, Remy asked Ororo about one of the “cards”.

Remy: Yeah, what this mean?

Ororo: That means the b , b is always your y -intercept so you look at the four.

Where's your graph? You look at your 4 and then 10. And then ten right here, 10, yes.

Prior to the flipped lessons, Remy would ask the teacher to explain a problem/concept, and then he would explain it to his group. The above excerpt illustrates a shift in the

group dynamics and more collaborative interactions between the group members. This exchange also demonstrates Ororo's understanding of the algebraic and graphical representation of the function.

Professor X, clearly moved by what he was witnessing, approached me mid-class with a grin. "Randolph, you're a miracle worker," he said, his voice brimming with gratitude. For him, the shift was revolutionary: students who had never before completed a full assignment were now working diligently from bell to bell. Those with strong mathematical skills had grown even stronger, completing their work quickly and with minimal guidance. Meanwhile, students who had been considered weaker or more prone to distraction were fully engaged, collaborating and contributing in ways that Professor X admitted he hadn't seen all year.

By the end of the class, the students were still focused, replaying videos, consulting their notes, and helping one another. The room hummed with a collective determination that defied its usual patterns. For many, this was the first time they had worked with such sustained focus and enthusiasm, a testament to the power of accessible resources, a supportive learning environment, and a shift in expectations that gave every student the tools to succeed.

Student Reactions to Video 2

Based on the student interviews and the focus group interview, which were conducted immediately after the second flipped lesson, students liked: the videos being in their native language, the length of the video, their teacher explaining the vocabulary in the video, and the notetaking guide.

Videos in their native languages

During his student interview, Hank responded to my question about which language he watched the video in by saying, “my language, Pashto”. When the focus group was asked about the translated videos, they said they were helpful as well.

Int: What about the translations? For those that listened to the translation is the translation helpful?

Hank: Yeah, translation is helpful. (Other students nod their head in agreement)

Although Jean and Madelyne opted out of participating in the focus group interviews, they were both willing to answer questions about the videos and the lessons off camera. When asked about their use of the videos both girls found them helpful and used them to complete their assignments. Madelyne listened to the video in Arabic and Jean listened to it in Vietnamese. During class students were playing the videos in multiple languages while they worked on the assignment.

Length of video

During the focus group interview, all the students except for Remy stated they liked the length of the videos. Remy said he would like the vocabulary video and a video of sample problems to be combined in one video so he would not have to click on multiple videos.

Int: Can they be separate videos too?

Jubilee: Yes.

Ororo and Hank nodded yes

Remy: Yeah.

Int: So that the video is not too long. Because umm a so he said that he liked the long (referring to Remy). If the video was longer, what do you guys think about the length?

The rest of the group shook their heads no to the video being longer.

Int: Shorter? The first video was only about 5 minutes. This video was 8 1/2 minutes.

Jubilee: My attention span personally is not very long, so like a long video, I'm going to get like bored.

Int: OK, so that 5 minutes 5 to 6 minutes is a good place? And then so maybe if we do it, we'll do like a five- or six-minute video with all of the vocabulary words?

Hank: Yeah.

Int: And then another 5-to-6-minute video with some sample problems?

Multiple students: Yeah.

Remy: Every like 10 minutes cause you know the first the first video, how for the first video would be the questioning, like solving the problem, then the later on the extra minute would be like about the vocabs and definitions of them of the teacher explaining it the meaning of it.

Int: So, OK, so that they're saying they want it split into two separate videos, so just the vocabulary video, and then just the problem video. But you want it all?

Remy: Like together. No, for the people who want it that way though. Like you know.

Int: So, give the option to have it all together, but also the option to have it split is what you're saying?

Remy: I'll just say for me, yeah, altogether.

Int: You like it all together.

Remy: So that I don't have to go to like, you know, back and forth like you know, going back to the definition and go back to the questions, if they're like together, you would, yeah.

Their teacher explaining in the video

During the focus group interview, all the students agreed that they liked having their teacher create the video.

Int: What do we think about the videos?

Jubilee: I like it, it's helpful

Int: How is it helpful?

Jubilee: It's like. As good as I told you. It's what, it's what I said before. It's like Professor X is just teaching me. It's not like a random YouTube or something.

Int: OK. Anybody else?

Multiple students: What she said. Same.

Remy: Oh yeah, I would say it's helpful cause it's Professor X.

Int: It's helpful cause it's Professor X?

Remy: Yeah.

Explanations of content vocabulary

The decision to create a video explaining the vocabulary was made after doing a preliminary review of the data collected after the first flipped classroom lesson. During the focus group interview, all the students mentioned finding the explanation of the content vocabulary helpful.

Int: OK, so going forward would it be helpful because last time when we talked, someone said that having the vocabulary before it would be good? So this time we did a lot of the vocabulary to make sure, so even if we work problems with it also would be good to have the vocabulary, like maybe a vocabulary video and then a working problems video?

Remy: Yeah. For me. The teacher would just like add a vocabulary on another page and then another page for the video would be like, you know much better.

Int: When you said so on the note taking guide?

Remy: You're separate, like you know for the vocab and for the and then the problem.

Int: So have a vocabulary page and then have a separate problem page. Not mushed together, no? OK.

Notetaking guide

During the focus group interview, all the students said they found the notetaking guide was helpful.

Int: Is it helpful or not helpful? The note taking guides yes or no on those to take notes while watching the video?

Remy: Yes.

Jubilee: Mmhmm

Int: What? How does that help?

Remy: The things that you want to do.

Jubilee: Kind of because like when I write something I remember it

Int: OK. What were you saying?

Remy: Oh, this the same thing. Just like if you don't know the words or the definition of the, what is it the words you can just copy it down, write it down in your notes and memorize it and like, when you don't know, you can check it up later on, maybe in the future.

Teacher/Researcher Observations Related to Video 2

Both the teacher and I noticed that students were asking more conceptual questions as opposed to vocabulary or word meaning questions. For instance, during the first flipped lesson Remy asked about how to add terms with a variable to find the area using the area model.

Remy: Help and one more one more question. How do I add up if they have x ?

Professor X: So. So this one you can't add with anything because you got the x^2 .

But I can add $6x - 1x$. What's $6x - 1x$?

Remy: $6x - 1x$ is gonna be $5x$.

Professor X: Yeah. So now you'll have $3x^2 + 5x - 2$. That is the area of this thing right there. Write that down.

Remy: Mmhmm

Revisions Needed

During the focus group interview the students shared that they would like videos with the vocabulary explained and sample problems worked.

Int: Would you want the definition? So is it better to have the words explained first or after the problem you want them after? What about? What about you? Yeah, before or after?

Oro: Before

Hank: Before

Remy: After

Jubilee: The vocabulary? So like when? Before.

Int: What about your vocabulary before?

Remy: Yeah, also after.

Int: Why? Why do you say after I'm interested?

Remy: Wait can you can you say again one more time.

Int: So if I gave you vocabulary, we're doing the video right? We have vocabulary and we have them working the problem, do you want your vocabulary first and?

Remy: Yeah. So you know if the if the teacher explained the vocab first and later on if they're solving the problem that we understand which one is which and which the meaning, which one is.

Int: So you understand which and OK, and then you said so for the vocabulary. If we do the note taking, we have all vocabulary on there like maybe the

front page. And then some sample problems to work through on the back and that would be perfect?

Remy: Yeah. Because if the teacher going to start off with the video and then they don't understand, they have to go, they have to wait for the, you know, extra time for the for the vocab to pop up and then after they knows that they're going to like wind back and go back to the like the first questions and solving extra terms.

Students also had suggestions about how they access the videos. They stated that they would prefer to have the videos housed on a learning platform, perhaps by unit. They did not like having to use their school email to access the videos because they had to "click" too many things to get to the video.

Summary of Effective Strategies

The findings from both flipped lessons indicate that multilingual students benefit from instructional videos in their native language as well as videos that explain key vocabulary and provide step by step explanations of sample problems. My data support previous findings that the video and the in-class activity need to be intentionally and explicitly connected. Throughout the flipped lessons students referred to their notetaking guides and the video to assist them with the in-class activity. There were multiple instances where students pulled up the flipped video to use as an explanation to show their group members how to do something in the in-class activity. They felt more comfortable attempting problems because they were already somewhat familiar with the content since the teacher used problems from the in-class activity as examples in the video. The teacher also consistently told students the information they needed to

complete the assignment could be found in the video. Students consistently stated that they prefer to hear their teacher explaining in the videos and they used the notetaking guide to record notes while watching the video and later to use in class to aid them in completing their assignment.

Based on these findings, I am making the following recommendations for designing a language accessible flipped classroom model.

Video Design In addition to being translated, videos should be less than 10-minutes and created by the teacher (or someone the students are familiar with). The videos should be created using screen casting software and include sample problems being worked and content vocabulary. The content vocabulary should be at the beginning of the video, preceding the sample problems.

Connect the video to the in-class assignment The video content should be explicitly connected to the content from the in-class assignment. For instance, the teacher and I selected problems from the in-class assignment to use as the sample problem/guided practice in the video. The vocabulary in the video should include visuals and cover words students will encounter during the in-class assignment.

Provide a note-taking guide The note-taking guide should mirror the content covered in the video. It should have the images and problems used in the video (and consequently the in-class assignment). The note-taking guide should also include a space for students to take notes and record words they do not know.

In-class activity The in-class activity should explicitly connect to the content covered in the video and allow students opportunities to collaborate with one another. During this

time if students ask questions that can be answered by watching the video, the teacher should suggest they watch the video before answering their questions.

Student Usage of Flipped Class Materials

Having given a detailed description of the students' interactions with the videos and class material, I present my findings on specifically how multilingual learners used the videos. I derived seven major themes from the codes from this study. These seven themes are: learning autonomy, peer collaboration, translanguaging processes, pride in use of home language, comprehension and understanding, motivational impact, and confidence in mathematics. Three of these themes address my second research question: *How do multilingual learners use videos provided in their native/home language as part of a flipped classroom?* and four of the themes address my third research question: *How do multilingual learners perceive the use of mathematics videos in their native/home language as part of a flipped classroom approach?* The three themes that emerged regarding the second research question are: learning autonomy, peer collaboration, and translanguaging processes.

Learning Autonomy

Autonomy in mathematics classes refers to the degree to which students take ownership of their learning process, make choices about how they approach problems, and develop self-directed strategies to explore mathematical concepts. Autonomy promotes deeper engagement, critical thinking, and confidence as students actively participate in their own learning. The theme learning autonomy addresses how students engage with videos at their own pace, how students use and reference their notes and

notetaking guide, and how students rewatch the videos and use them to reinforce mathematical concepts. Students' autonomy was apparent both in my observations of students working in class and in their reports of activity inside and outside the classroom. As reported in the detailed analysis for RQ1, I observed students using their notes from the videos to make progress and assist other students in making progress (see Figure 6 and Teacher/Researcher Observations Related to Video 1). Multiple students reported taking notes from the video and using those notes to help them solve problems. For instance, in her student interview, I asked Emma about taking and using notes:

Me: Did you take notes while you watched the video?

Emma: Yeah I did

Me: And did you use those notes to help you with the problems?

Emma: Mhmm. At first I forgot everything. Like, I can't find it that's why I'm writing down everything.

Additionally, three students reported watching the video more than once (Hank and Emma three times, Ororo five times). This relates to autonomy because it illustrates how students took responsibility for their own learning. They watched the videos multiple times to understand the material. Prior to this, when given an assignment, students would immediately begin asking the teacher how to do the work. The teacher spent the entire class period moving from group-to-group reexplaining the same things. Students rarely sought help from one another, nor did they attempt to complete the assignment without teacher assistance.

The teacher's role shift from the sole purveyor of knowledge to a facilitator of learning is further demonstrated when Jubilee's groupmates held her accountable for

watching the video. During the second flipped class, Jubilee came in late and apparently did not watch the video. She started her assignment and asked a couple of questions about content vocabulary covered in the video. Remy and Ororo, both asked her if she watched the video because her questions indicated that she did not. When she responded no, Remy told her to watch the video. Professor X also came by their group and told her to watch the video. After she watched the video, she stopped asking questions about what words meant and started having discussions with her groupmates about the characteristics of the quadratic function graph.

During his interview after the second flipped lesson, Professor X expressed his excitement about how the students worked through the assignment without his assistance. He noticed that the students were engaged and working through the card sort in their groups without asking him a lot of questions.

Professor X: Yeah, yeah. The kids, like (laugh) OK. And I don't know, like cutting paper. You know the hands on that, that part of it is like I looked at first block. I was just like what is happening right here? No one was talking, they were all cutting and trying to figure out where it was going. And you know? But then, they eventually went into talking. And it was like they were engaged without my help or anything of that I was like, what, what is happening here? What could have happened here? Just they, like first block especially needs prodding. Like hey, where what, what's happening here? Because they zone out and they're, you know, doing something else and it's like they did it without any of that. I was like, OK, what the heck? So yeah, yeah, **success** is the right word.

Professor X repeatedly expressed his frustration with the lack of on task behavior and completion of assignments in both his first and second block classes. This lack of class engagement contributed to the decision for me to conduct the study in his third block class because he did not think the students in the other two blocks would adequately participate in watching the videos or doing the tasks. Nevertheless, he was pleasantly surprised by the students' commitment to working on the assignment in these blocks. He decided to implement the FCM using the translated videos in his other two blocks after he saw how successful it was in his third block.

Peer Collaboration

My coding of peer collaboration reflects how students used videos in their native language to collaborate with peers, especially in group learning and discussions. For example, Remy noticed his groupmates having difficulty with a problem and asked if they needed help. Ororo confirmed her need for assistance, so Remy started explaining the problem. Raven and Emma listened to his explanation along with Ororo and interjected with questions when they needed further clarification. Raven asked Remy how he got $3x^2$. He explained his process for getting $3x^2$. Ororo and Emma did not understand what to multiply to get $2x^2$ in one of the boxes in the area model problem, so they asked Remy to explain. After he showed them how he got $2x^2$ Ororo tried another problem to confirm her understanding.

Remy: Need help?

Ororo: Yeah, I need help on this one right here

Remy: You know, they get $3x^2$. What do you need to put in these two boxes?

You're missing, this one missing one thing and this one missing one thing.

Raven: How are you getting $3x^2$?

Orooro: That would be 3.

Remy: How do you get x ?

Orooro: Three times two?

Remy: Look. See like this like this. (He refers to his notetaking guide)

Raven: It's uncomfortable.

Remy: Like this, x (referring to his notetaking guide) x^2

Orooro: How did you get this $2x^2$ like what did you multiply?

Remy: In order to do that you have to like this term x , that's term x , that's 2. The area is $2x$ so it's going to be two like this.

Emma: Ohhhhhh

Orooro: Oh, like three and then the x is right here?

Remy: Yeah, like this see? This one right? This one $10x$, $4x$, 3 (Orooro said 3 with Remy as she is following along with his work). $4 * 3$ is 12 and then got it in order to get $3x^2$ you need $3 * x$ it's going to be $3x^2$ plus you know that's our x and that's $2x$ is going to be two x . You're going to put it like this. And that's how you do it.

Recall that in class observations prior to the flipped classroom intervention, students worked primarily independently, with a few students engaging in group conversations that were unrelated to the mathematical task and some students copying work from one mathematically proficient student verbatim. During the two flipped classroom sessions, I observed students working together in ways that were not observed during previous observations and that the teacher reported to be unusual for the class. For

instance, Emma asked for help on a problem and she, Remy, and Ororo collaborated to arrive at the correct answer.

Emma: Remy explain.

Remy: What's up?

Emma: How you do this?

Remy: Explain what?

Emma: How you do this? (shows a problem on her paper)

Remy: 3 times 3? Three times x^3 ? Now what what is x times $3x$?

Emma: Times $3x$? I don't know

Remy: You just we just did. We just did this a moment ago. So 3 times x so $3x$ is going to be three x squared and x times positive 1. The $1x$ you're going to add it going to put the sign right here (he shows her using his paper). In order to get (-9) ...

Emma: Where you get the negative nine from?

Remy: We're going to do it negative $-3 * 3$ plus. You know, first you're going to do this. After that, you're going to do this $(-3 * +3)$ is going to be -9 and then -3 times $+1$ is going to be -3 . After that you going to add these to the middle part. Negative 1 plus negative 9 is gonna be wait (he pauses and looks at his paper)

Ororo: Negative $10x$

Remy: Naw negative 1 plus negative 9 is gonna be, shoot... Yeah, I'm wrong. This one's gonna be $-10x$.

During this collaboration Ororo and Emma continued to gain a better understanding of the material. This also highlights how this collaboration helped Remy see his mistake. Peer collaborations extended beyond the students' small groups. Students began interacting with different groups and collaborating across the classroom. During the second flipped lesson Anna noticed Hank's group working through the card sort and asked him a question about one of the quadratic function statements. This was a radical transformation because prior to the implementation of the flipped lessons Anna was regarded as one of the stronger mathematics students and Hank was deemed as a derelict student. However, the dynamics of the students' behaviors transformed into a mutually inclusive ecosystem of collaboration and collective understanding.

The teacher also noticed the shift to collaboration with students completing the assignments. During his interview after the second flipped lesson, Professor X attributed the students' ability to work through the problems to their collaboration.

Professor X: And is like having the groups actually helped is like that back group

I could hear is like, oh, you know, they were like working through talking through, I think and umm so in Hank's group, yeah. He, I heard him like talking about the sentences. And yet they were able to work through the problems, you know with help and it's like, God, OK, actually like teamwork, group work.

Professor X once again was pleasantly surprised by the level of collaboration demonstrated by Hank, Scott, and Kevin. This is a group which was regarded as consistently off task and not interested in learning the material but after they were given

access to content videos in their home languages they became vibrant participants in this class's educational ecosystem.

Translanguaging Processes

As discussed in Chapter 2, translanguaging refers to the process by which multilingual students use their languages as an integrated communication system. It involves the dynamic and fluid use of multiple languages within a single conversation or context, allowing students to draw on their entire linguistic repertoire to make meaning, communicate effectively, and express themselves fully. This may involve students switching between languages however these modes of communicating are not limited to speech but may also include gestures, use of diagrams/pictures, referencing videos and notes to name a few. The theme translanguaging processes addresses how students use multiple modes to communicate.

Collaborations in a common language were very prevalent during the flipped lessons. This was especially true during the second flipped lesson when the students were working on the card sort activity. This activity required students to look at statements about a quadratic function and its graphical and table representation in a contextual problem and determine if the statements were true or false. The statements and the text were in English, but many students used their home language to discuss their reasoning about each statement before discussing it as a whole class in English. The following picture (*Figure 10*) shows the Pashto/Urdu and an Arabic group working on the card sort activity. During this activity the students in these two groups discussed quadratic function statements in their home languages. They asked the teacher and the researcher or students in other groups that spoke a different language, questions in English. Students fluidly

switched between their home language and English as they worked through the assignment.

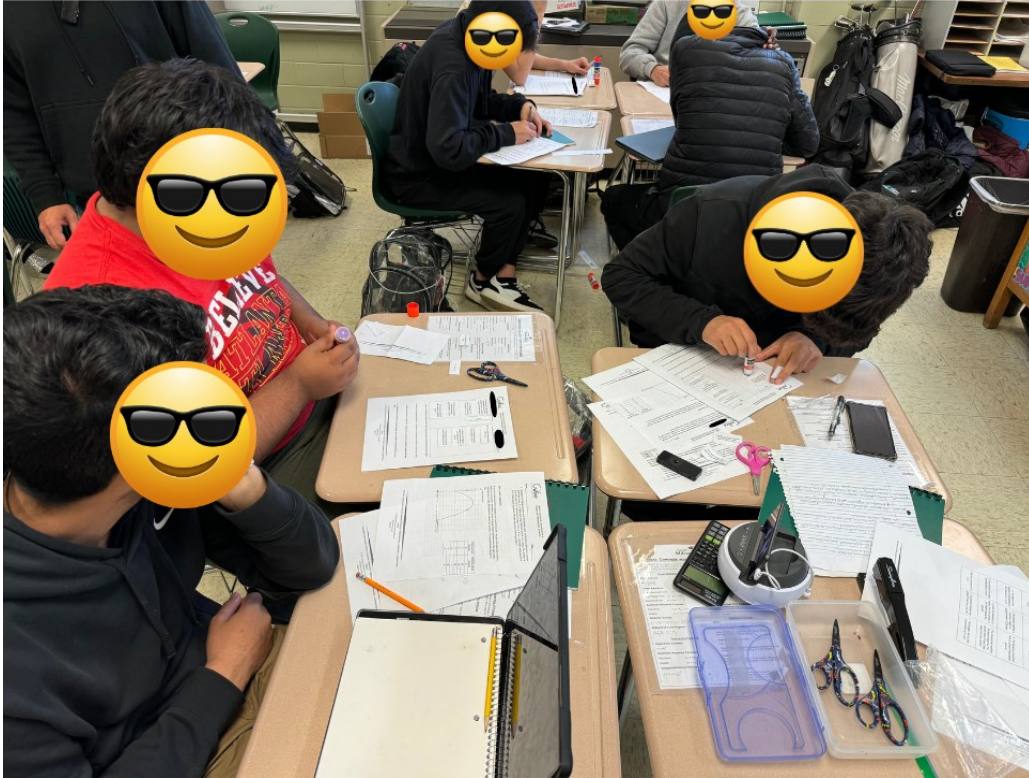


Figure 10

Student groups working on the card sort activity

There were also multiple instances of students using the videos to help them explain how to work on a problem. For example, Ororo used the video in the first flipped lesson to help her explain how to work a problem to Emma. Hank and Scott used the video from the second flipped lesson to help Kevin understand information on the in-class assignment. Two groups of Arabic students used the video from the second flipped lesson to help them reason through the card sort activity. When students used the videos in this manner they would pause and rewatch sections of the video pertinent to the

problems they were working on. They would point at the images or equations in the video and discuss in a common language. For homogenous language groups this common language would often be their home language. For heterogeneous language groups the common language was English.

Students also used their notetaking guides to explain problems to one another, often referring to their notetaking guides as they explained their problem-solving process. They would use the images on the notetaking guides to help illustrate their thinking. Remy referenced the notetaking guide while explaining a problem to his group during the first flipped class.

Remy: Look. See like this like this. (He refers to his notetaking guide)

Raven: It's uncomfortable.

Remy: Like this, x (referring to his notetaking guide) x^2

Ororo: How did you get this $2x^2$ like what did you multiply?

Remy: In order to do that you have to like this term x , that's term x , that's 2. The area is $2x$ so it's going to be two like this.

Emma: Ohhhhhh

During his explanation, Remy consistently referred to the images and his work on the notetaking guide.

The notetaking guides were written in English, but students took notes in multiple languages. For instance, Jean took notes in Vietnamese, Madelyne took notes in Arabic, and Raven took notes in German (pictured in *Figure 11*) while Hank, Ororo, and Jubilee took notes in English.

NOTES :

Video Example 1

$\times$

$+3$

$10x$	$10x^2$	$30x$
4	$4x$	12

$10x^2 + 30x + 4x + 12$
 $10x^2 + 34x + 12$
 $(10x + 4)(x + 3)$

Words I don't know

Was ist ein
Trinuum

Video Example 2

What are the factors of the trinomial $x^2 + 7x - 18$?

$(x+9)(x-2)$
 $x^2 - 2x + 9x - 18$
 $x^2 + 7x - 18$

x^2	$-2x$
$9x$	-18

Questions that I have

Figure 11

Raven's notetaking guide from the first flipped lesson with notes in German

Students also used gestures to convey meaning. During the second flipped lesson when the teacher asked the class what the bird was doing, Hank used gestures to demonstrate the bird flying, diving to catch the fish, and coming out of the water. The

following pictures illustrate Hank's use of gestures to demonstrate what the bird was doing.



Figure 12

Hank using gestures to demonstrate the bird flying to get to a maximum height before diving



Figure 13

Hank using gestures to demonstrate the bird diving to catch the fish and grabbing the fish with its beak

The implementation of the FCM in students' native/home language led to significant transformations in student autonomy and collaboration. By taking ownership of their learning process, students developed self-directed strategies and utilized various resources, such as videos and notetaking guides, to reinforce their understanding of mathematical concepts. This flipped classroom approach also fostered a collaborative environment where students actively assisted each other, transcending previous patterns of dependency on the teacher. Students integrated translanguaging processes further enriching the class experience by allowing multilingual students to leverage their linguistic repertoire. Overall, the use of instructional videos in students' native/home languages cultivated a classroom environment which promoted learning autonomy, peer collaboration, and translanguaging processes.

Perceptions of the Use of the Videos

How do multilingual learners perceive the use of mathematics videos in their native/home language as part of a flipped classroom approach?

The four following themes emerged in reference to answering research question three: pride in use of home language, comprehension and understanding, motivational impact, and confidence in mathematics.

Pride In Use of Home Language

Pride in the use of one's home language within an academic setting is a powerful affirmation of identity and cultural heritage. When students see their language represented and valued in the classroom, it fosters a sense of belonging and self-worth (Aleksić & Garcia, 2024; Civil & Andrade, 2002; Civil, 2016; González et al., 2005; Hamman-Ortiz et al., 2025; Kumar et al., 2019; Moll & Gonzalez, 1994; Zain &

Rohandi, 2009). It reinforces the idea that their linguistic and cultural backgrounds are assets, not barriers, to their education (Hamman-Ortiz et al., 2025; Paris & Alim, 2014; Setati et al., 2008; Tjandra, 2024). This pride goes beyond mere communication; it is an acknowledgment of the rich history, traditions, and stories embedded within their language. By incorporating home languages into the curriculum, schools create an inclusive environment where diverse perspectives and experiences are celebrated (Aleksić & Garcia, 2024; Civil, 2016; Crawford, 2013, González et al., 2005; Kumar et al., 2019; Moll & Gonzalez, 1994; Zain & Rohandi, 2009). This approach not only enhances students' academic engagement and performance but also promotes cross-cultural understanding and respect among peers (Aleksić & Garcia, 2024; Hamman-Ortiz et al., 2025). Ultimately, pride in the use of home language in an academic setting empowers students to embrace their unique identities and contribute meaningfully to a diverse and dynamic learning community.

When I initially spoke to the class about the study and explained there would be videos available in different languages, the students were excited. When they were given access to the folder with the videos, students eagerly looked for their language. During both flipped classes students were encouraging other students to watch the video and saying things like, “it's in your language you can understand.” The Arabic speaking students watched the video in Arabic and completed their assignment collaboratively while speaking in Arabic in their small group. The Pashto and Urdu group watched videos in Pashto and Urdu and then spoke in these languages to collaborate on the assignment. During the student interview after the first flipped lesson Hank said he watched the video in Pashto and Urdu because he understood both languages. As

mentioned before, prior to the videos Hank was seemingly apathetic about doing work in this class. However, he was excited about having videos where he could understand what the teacher was explaining.

Int: So did you watch the video?

Hank: Yeah, I do, sorry

Int: Which language?

Hank: Is I'm my home language Pashto.

Int: You watched in Pashto?

Hank: Yeah.

Int: Oh, hold on. I'm sorry.

Hank: And I watch one time Urdu. Yeah

Int: Oh yeah, so you watched it in English and Urdu, which was.

Hank: Yeah. I'm watching.

Int: So Pashto.

Int: Or do did you watch any English too or no?

Hank: No, no.

Int: OK. Why? Why Urdu as well? Just curious or?

Hank: Its just like I know Urdu. He helped me explaining. Yeah. And Pashto my home language. And I'm understand clearly.

Not only did he watch the videos, but he watched them several times and I witnessed him encouraging his group members to watch the video as well. He showed them the Urdu translation during class and they were excited as well. The entire group worked on the in-class assignment and remained on task for the entire period. This change in behavior was

noticed by other students. During the first focus group interview after the first flipped lesson Remy commented on Hank's participation in class.

Remy: Yeah. Now that I see this if I don't get words you know before that,
 Professor X explain words in English and he don't, he don't get it. He just
 playing around. But now he now that he getting his start you know doing
 the work. All that.

Int: Actually doing the work?

Hank: Yeah.

Int: You agree with what he said?

Hank: Yeah.

Here Remy is attributing Hank's change in behavior to him having access to videos in his language. When Remy described Hank as "just playing around" during class both Emma and Ororo nodded their heads in agreement. They also agreed when Remy said Hank started doing his work. Hank agreed with Remy's assessment.

During both his student interviews Hank mentioned having the videos in his native/home language. During his first interview he said the videos made him want to do his work. When I asked him why, he sat up straighter, hit his chest and said because it was in his language.

Me: And has watching the video made you want to work on problems more in
 class? Has it helped you want to actually do your work in class more?

Hank: Yes, yes, it's work me.

Me: Why do you think that? Is why so?

Hank: Because MY language (he hits his chest) and I'm understanding clearly.

There was palpable pride in his bearing when he said, “MY language.” This pride and excitement were displayed numerous times by the students. Throughout this study I noticed the students were so excited and happy to see their languages represented. Multiple students were watching the videos simply because they saw their language. They would have conversations among themselves and look for their language. When they found their language, they would tell other students “There is my language” and the fact that the language was present made them excited about learning the material. Having access to the videos in multiple languages made them want to watch the videos because they had never seen their languages in this American academic setting before. Professor X shared instances of students being excited about seeing videos available in their language with genuine enthusiasm during his interview.

Professor X: I said I had a student in first block who saw Burmese and was like, super excited just to see Burmese. There was like, you know, I watched it in Burmese and I understood. And, you know, was so excited. I was like, OK.

These findings highlight the pride students had in seeing their languages incorporated into their lessons. This pride prompted a desire to engage more actively with the content.

Comprehension and Understanding

Students reported increased comprehension and understanding of the mathematical ideas, particularly with respect to vocabulary. My observations support these reports. The theme comprehension and understanding centers around whether

students feel they better understand the mathematical concepts when they can access content in their native language.

Prior to the introduction of videos in students' native/home language Hank and his group were often off task and rarely completed assignments. Hank would joke and talk to his groupmates. If they did complete work to turn in, it was often copied from their groupmate Scott. They would simply copy Scott's work without trying to understand how to do the assignments. However, after providing students access to videos in their native/home language this groups' in-class behavior changed. They started participating in the class discussions and trying to do the assignments. During the second flipped class Hank asked, "Can I explain it?" volunteering to go to the board to explain a problem. This was the first time he ever volunteered to go to the board. During the second student interview when I asked Hank about the use of the videos after the second flipped lesson he stated that the videos helped him understand.

Int: OK. And do you think it helped with understanding today's lesson? (He nods yes) Yeah. How so can you tell me?

Hank: Yeah because is like the first work. I'm not understanding the English and he explain me in the my language and I understand.

After implementing the first flipped lessons I conducted the first student focus group interview. During this interview when I asked if the videos were helpful all the group members said yes because it helped them learn the content and understand. Hank also highlighted that the videos explained the content in "your" language and the other students in the focus group agreed with him.

Emma: Because like if you if you don't know what to do then like you need to learn more.

Int: So, if you don't know how to do something, you need to learn it and the videos help with the, helped you with learning

Emma: MHM

Int: What were you going to say?

Ororo: The video helped me a lot because it just explained it. Yeah, it's like, how do you do this?

Int: Because it explained it to you?

Hank: And it explain in your language.

Other FG Members: Yeah. Yeah.

After implementing the flipped lesson, the teacher noted an increase in student understanding and engagement with the material. During the second interview after implementing the flipped lessons the teacher enthusiastically commented on the change in his classroom dynamics and students' behavior. He was impressed and a little awed with how the groups worked together and their ability to tackle complex problems during class.

Professor X: You know, closing was like, hey, let's talk about a few. That's like, you know, I think a little more challenging, you know.

Int: And they got them

Professor X: I know I know like some of them like I was so impressed, like those answers. Like Oh yeah, yeah, you know, this is it. This is why. And I was like OK. OK, wow. Wow. I'm telling like, every group I walked by like,

every table was like they had some really good answers and I was just like what happened? Who are you?

The teacher stated that he noticed increased understanding in all his classes. He shared the videos and notetaking guides with every block of students. During our first interviews and when I was planning for this study Professor X often complained about the students in his first two blocks. He said they were easily distracted and constantly off task. He was frustrated with their class performance but after providing the videos and flipping the lesson he saw a change in how his students interacting with the content.

Professor X: But then they were able, like all of my classes, were able to work through the work. And I think at the end of the class, like you know the class was like. Oh, hey, you know, like we did this thing and you know, like, this hasn't been normal this year. And you can see, yeah, when they got to like the second part of it where it's like, you know, the dolphin and the fish and the bird, you know, like a lot more reading and understanding.

As evidenced above, Professor X noticed more student understanding in all three blocks of class after implementing the flipped lessons.

Motivational Impact

Students appeared more motivated and enthusiastic about learning mathematics during the flipped classroom sessions. For instance, Professor X noted the increased engagement from students in all three of his classes after he provided them access to the videos and the notetaking guides.

Professor X: And and you know, like my like all three blocks were engaged, you know, pretty much the entire time and you know.

Int: OK, so all three blocks had access to all of the videos, OK. And the note taking guide?

Professor X: They did. They did.

The theme motivational impact focuses on how the use of videos in students' native language affects their enthusiasm for learning, as well as their engagement and participation in the flipped classroom.

The teacher credited the availability of videos in multiple languages as a key factor in motivating students to watch them before class, which in turn increased overall engagement during lessons.

Professor X: So that, like, let's put it as like motivation for sure. I think just having like hey, there's my language right there. I can click on the video and it's going to be something that at least you know, I'll have a chance to understand easier than English I think that's, you know, yes, the answer is yes...So yeah. Yeah. No, I do think having the languages help motivate some students to you know even like to engage and try in the lessons like first and second block, I definitely had students who normally like zone out and whatnot and they engaged in the lessons it's definitely a positive thing.

The teacher described the day prior to the second flipped lesson as chaotic and riddled with interruptions to instruction. However, despite multiple school distractions, he noted that students were determined to get access to the videos so they could watch them prior to class. This reflects their growing motivation to be prepared for lessons and to fully participate in in-class activities.

Professor X: And like I said yesterday, it was some crazy stuff with testing and fire alarms and whatnot and so like, I mean some didn't have like a chance to, like get to the video and whatnot. And they were scrambling like I had. I had the kids come to me this morning was like, hey, you know, I don't have access to the video. Can you make sure. And they were able to watch it before they got to my class or during lunch.

Interestingly, this drive to access the videos extended beyond students who were typically diligent about completing their work. It also included those who were less enthusiastic about homework or class participation.

Professor X: It definitely helped. Like I said, I had kids coming in the morning. It was like hey, I don't have access to it. You know where where is the video? Where where's going on it or I missed and and you know, I was like, oh, heck yeah

Int: Are these kids who normally try to get their work, or is that like a? Did you hear some different personalities trying to get, they wanted to have access?

Professor X: It was different.

Students who typically did not show interest in completing assignments began seeking out videos they had missed. This shift in behavior carried over into the classroom, where these students became more engaged during lessons. Professor X expressed surprise by the level of student engagement in all his classes.

Professor X: I was surprised. I was surprised at like 100%. How well today went. Whole 100%. Not, you know, even first and second block you saw when they came out like what in the world? Like third block. I mean second

block they talk and they were off task some that's everyday but like they still were engaged in the lesson and you know like. OK, and I do like they were able to pull up the video and like work through and, you know, kind of figure it out. The videos definitely helped in my class for sure.

This was especially true for the flipped lesson on the Friday before spring break, a notoriously challenging day to keep students focused. However, the flipped lesson proved effective in maintaining motivation and engagement.

Professor X: Especially like the day before spring break too. Yeah. Yeah. Like I have I have like I kind of like I thought this would be a disaster to be honest, I was like you know, like last day, you know, whatnot. But kids, kids are engaged.

Based on the engagement observed across all three blocks, Professor X deemed the instructional day a success.

Professor X: Like just like they like first block especially needs like prodding like hey, like, where what, what's happening here? Because like they zone out and they're, you know, doing something else and it's like they did it without any of that. I was like, OK, what the heck? So yeah, yeah, success is the right word.

The flipped videos also allowed stronger students to become motivated to extend their learning. Jean, Madelyne, and Scott are students who generally perform well in this class. They complete their work on time and assist other students in the class. All three students watched the flipped videos in their native languages (Vietnamese, Arabic, and Urdu). Prior to the introduction of the flipped videos, they waited for Professor X to teach

the class and answer questions, but with the use of the videos they were able to complete the assignments faster. They also demonstrated deeper engagement with the content.

Professor X: The kids were engaged in in that third block. I mean, you could see it was, that was fantastic in there and even like I had, you know, this student on the far side of the class went through. He was asking me like some, you know, great questions. And he was like, hey, is this right? And he had some great answers I was like, wow, wow. OK, OK.

Professor X attributed the students' motivation to watch the videos on the videos being available in their native languages.

Professor X: So that, like, let's put it as like motivation for sure. I think just having like hey, there's my language right there. I can click on the video and it's going to be something that at least you know, I'll have a chance to understand easier than English I think that's, you know, yes, the answer is yes.

My observations align with his statement. During both observed classes, students frequently pulled up videos in various languages to assist with their assignments. They also encouraged peers to watch the videos, often citing the availability of their native language as a key benefit. Although the first and second blocks were not part of this study, the teacher's observations of their post-flipped lesson engagement further support these findings.

Professor X: So yeah. Yeah. No, I do think having the languages help motivate some students to you know even like to engage and try in the the lessons like first and second block, I definitely had students who normally like

zone out and whatnot and they engaged in the lessons it's definitely a positive thing.

Perhaps one of the most salient indicators of having the videos available in multiple languages promoting students' motivation to participate in class was revealed during the first focus group interview. Remy noticed Hank and his group working on the assignment in class and attributed this to the videos being in different languages. Hank affirmed that having access to the video in his home language encouraged him to work on the assignment in class.

Remy: Yes, of course you have translation AI for most of the people who don't understand, like fluent English or understandable. They can learn from their own language using the AI translation, which is better for them.

Hank: Yeah

Remy: Especially for him (indicating Hank)

Int: Yeah, especially for him? He said that already. He listened to it in two different languages because he knew two.

Hank: Yeah

Remy: Yeah. Now that I see this if I don't get words you know before that, Professor X explain words in English and he don't, he don't get it. He just playing around. But now he now that he getting he start you know doing the work. All that.

Int: Actually doing the work?

Hank: Yeah.

Int: You agree with what he said?

Hank: Yeah.

This heightened motivation to engage with flipped videos not only improved students' preparedness for class but also fostered a noticeable increase in their confidence, as they began to approach mathematical challenges with greater self-assurance and a willingness to participate actively in problem-solving.

Confidence in Mathematics

Confidence in mathematics classes refers to a student's belief in their ability to understand, engage with, and solve mathematical problems. It involves a sense of self-efficacy and resilience when facing challenges, fostering a positive attitude toward learning math. In examining the impact of the flipped lessons, I noticed several instances where students demonstrated increased confidence in their mathematical abilities.

Examples of mathematical confidence are willingness to attempt new problems, explaining their thinking, asking questions, helping others, perseverance, and engaging in mathematical discussions. These behaviors were particularly evident during collaborative group activities, where students supported one another and built on each other's understanding.

Confident students assist classmates, showing that they not only understand the material but also believe in their ability to explain it. For example, during a group activity, Remy demonstrated confidence by helping Raven with an area model problem. Their exchange highlights how collaborative learning fosters understanding and builds trust within the group.

Raven: Add this together?

Remy: Add all of it

Raven: Huh?

Remy: Like this, just add it all up. That's it. $2000 + 600 + 40 + 200 + 60 + 4$ that's going to give you 2904 (he shows her using his paper)

Similarly, students who were typically more timid began to engage more actively in small groups. This included not just asking questions but also answering them, as seen in the interaction between Jubilee, Remy, and Ororo. Jubilee asked Remy where the vertex was because Remy is traditionally the stronger mathematics student in this group, but Ororo answers her.

Jubilee: Remy, where's the vertex again?

Ororo: At the top yeah, top.

Jubilee: So maximum and vertex is the same.

Remy: 4 point 2

Ororo: Yeah the top is actually the vertex

Remy begins responding with the coordinates of the vertex, but Ororo provides information based on an example shown in the video. Although Remy initially began to respond, Ororo took the initiative to provide an explanation, reflecting her newfound confidence. This moment is particularly significant because Ororo typically relies on others to answer questions but felt empowered to contribute during this instance. During her interview she was excited because she understood the content and felt confident enough to help her group with the assignment.

Int: How did you feel about helping someone today?

Ororo: It was fun. I was like, yes!

Throughout her entire interview after the second flipped lesson Ororo was smiling

and laughing. She was excited about understanding the work and getting the correct answers. Her positive attitude underscores how understanding the material can lead to an increase in self-assurance and enthusiasm for participating in class.

Hank, whose classmates previously described him as never paying attention or doing his work, not only worked on the assignment and collaborated in his group but also volunteered to go to the board to explain a problem. This shift in behavior demonstrates how a supportive environment and accessible material can transform a student's attitude toward math. When Professor X put the problem on the board Hank asked, "Can I explain it?" When he explained the problem correctly, he received several "good jobs" and some applause from the class. In his interview after this class, he said that he felt better about doing work in class. This recognition from his peers and teacher contributed to his growing confidence, as he shared during his interview.

Int: How confident do you feel about the material after watching the video? Did it make you feel better about doing the work since you watched the video, or did you feel the same?

Hank: Yes, some work is better. Some work. I don't understand. I am better. Right now.

Instances of perseverance further illustrate the growing confidence among students. Raven, for example, demonstrated determination when faced with frustration over a challenging problem. She did not give up but showed perseverance in trying to understand by asking her groupmates for help.

Raven: I'm about to cry, bro.

Remy: Well, we did this one. What is it? We did this first semester.

Raven: I forget

Remy: How you how you forget? Eight

Raven: I mean, this is easier than the multiply thing but.

Emma: Oh, you you solve this quad. You solve this quadratic?

Raven: Yeah.

Remy: 1 times (-9). No one minus negative nine. -8 so it's -8 and then -3 there you have it done. You got it?

Raven nods her head

Remy: Don't lie to me

Raven: I won't

Remy: So you got it, OK.

Raven: Maybe.

Remy: What do you mean maybe? It's only yes or no.

Raven nods her head yes

This exchange not only highlights Raven's perseverance but also Remy's supportive role in ensuring his groupmates understood the problem. Such interactions foster both individual and group confidence.

During the second flipped lesson, Professor X observed the students' perseverance with a text-heavy assignment. Unlike prior lessons, where students often relied on the teacher for assistance, they worked collaboratively to complete the task.

Professor X: And you can see, yeah, when they got to like the second part of it where it's like, you know, the dolphin and the fish and the bird, you know, like a lot more reading and understanding.

The students were not intimidated by the text. They persisted in working with one another to complete the task. They also did not request assistance from the teacher. In classes prior to introducing the flipped lessons, students would consistently ask the teacher for assistance with problems and would not attempt to work on problems with too many words. The students' determination to tackle the assignment independently demonstrates their growing confidence and engagement with the material.

Students also appeared eager for their hard work to be recognized in the gradebook.

Jubilee, for example, asked if her group would receive a grade for their work.

Jubilee: Professor X, does this go into our grades?

Professor X: Yes, of course, of course. All, all the hard work y'all been doing today.

Hank also asked, "This going in the gradebook?" When Professor X said yes, he smiled and another student said, "Well I appreciate it!" Students were excited about their work going in the gradebook and enthusiastically turned it in at the end of class. This excitement reflects how confident students had become in their abilities, as they took pride in their work and its evaluation.

CHAPTER 5

DISCUSSION

The idea for this study was motivated by my desire to recreate the learning experience that I witnessed shared between a group of multilingual students. I wanted to provide students with limited English proficiency more access to the content and create an environment where these students collaborated and actively engaged during class. In my 22 years of education, I have witnessed numerous instances of multilingual students passively sitting through mathematics lessons. I wanted to shift this narrative to one where multilingual students with diverse backgrounds were actively engaged in learning mathematics. I endeavored to do this by designing a study to investigate the impact of the FCM on multilingual students and determine effective strategies for designing flipped classroom instructional materials that cater to the unique needs of diverse learners in a secondary algebra classroom. The transformation from minimal participation to maximal participation that I observed during this study is perhaps best captured by the story of Hank. Let me tell you his story.

The Transformation of Hank

During the pre-interviews multiple students said that they were willing to work in any group but specifically requested not to be placed in a group with Hank. When I inquired as to why, they said Hank never did his work and he and his group just talked and did not pay attention during class. The teacher actually discouraged me strongly from trying to work with Hank and his group because he said they never did their work, and he did not think I would get any beneficial data from their group. He said that “all they do is goof-off and play.” When I interviewed the students, both Emma and Remy said that all

Hank did was play and talk and his group never did their work. Now, to be clear, I did not ask them about Hank because I did not know anything about him prior to this study.

However, this information was readily volunteered, which indicated to me that this particular student and his group had made a clear impression on the class and not necessarily a positive one. Despite everyone's misgivings about me including Hank and his group in my study, I decided to include them because they returned their consent forms and wanted to participate in the study. Hank also wanted to participate in the interviews in addition to the classroom observations.

During the pre-study interview, I discovered that Hank had only been in America for three years, he only had three years of schooling (he did not attend school prior to arriving in America), and he had only been learning English for three years. I also noticed Hank did not have an excessive number of absences, which was significant to me because it showed he wanted to learn. He just did not have the English proficiency to be able to access the information and the content, and so he made the best of a bad situation and entertained himself during class. During the implementation of the first FCM lesson, I saw an immediate transformation in Hank and his group. When Hank saw his language in the videos, he was so excited that he immediately started watching the Pashto video.

When he noticed his groupmates were not watching the video, he hit them on the shoulder and showed them the Urdu video (their home language). He told them the video was in their language, and they would understand. With his encouragement, his groupmates watched the video in Urdu. Hank watched the video multiple times in Pashto (his home language) and Urdu (another language in which he is fluent). After watching the video, Hank and his group began working on the assignment. During the first student

interview, Hank told me he watched the video because it was in his language, and he was able to understand. This confirmed for me that this was not a student disinterested in learning, this was a student who did not have access to the language to be able to learn, and that is a huge difference.

During the implementation of the second FCM lesson, Hank was a completely different student. He no longer just joked around in class. He started being a leader in the class, and it was such a wonderful thing to see because this student went from being inattentive and goofing off to answering questions in class and helping other students. When Hank noticed an incorrect answer on his groupmate Morph's paper, he quickly corrected him. He did not just give him the correct answer; he guided him through the work using his own paper to show him how to solve the problem. Throughout the class, both Hank and his group mates were completely engaged in the work. They worked through the problems with minimal assistance from me or the teacher. Hank occasionally asked me to come and check something because he wanted to make sure he was on the right track, but he understood the assignment. His group was working through the assignment so well that a group behind them noticed their progress through the assignment and started asking them for help. Here we see that Hank has moved from not paying attention to actually not just assisting his group but assisting other students in the class. Towards the end of the class, the teacher asked students to come to the board and share their work. Hank asked if he could go to the board. The teacher looked at him with a surprised expression and then said, "of course yes come on." When Hank stood up to go to the board, a hush came over the room. The entire class stopped what they were doing to watch Hank. They were riveted as if this was the best scene they had ever witnessed.

They had never seen Hank attempt a problem at the board, and they were raptly attentive. He went to the board and worked a problem, and you could hear a pin drop. When he finished working on the problem he turned and looked at me, so I gave him a thumbs up and he smiled. Remy called out “good job” which was followed by a chorus of good jobs throughout the class. Then the class started clapping for Hank. Even the students noticed the transformation in Hank, and they acknowledged his progress. It was truly a beautiful thing to witness and is a testament to the power of access.

During this study, Hank and his groupmates rebranded themselves as engaged, on-task, motivated learners. This transformation occurred within a week with the implementation of the modified flipped classroom model using instructional videos accessible to students in their home/native languages. I am calling this modified flipped classroom model the Language Accessible Flipped Classroom Model (LAFCM). The evidence supporting the efficacy of this model is further detailed in this chapter.

Summary of Findings

The introduction of the Language Accessible Flipped Classroom Model significantly enhanced classroom engagement and participation. Students were excited about the availability of videos in multiple languages, which captivated their interest and drew them into the material. Many students reported watching the videos multiple times in different languages to deepen their understanding, which aligns with previous studies on the flipped classroom model (Bhagat et al., 2016; Butzler, 2016; Cevikbas & Kaiser, 2020; Clark, 2015; Crawford, 2013; de Araujo et al., 2017; Freeman, 2011; Graziano & Hall, 2017; Katsa et al., 2016; Muir, 2015; Unal, Z. & Unal, 2017). In previous studies students watched the videos multiple times to increase their understanding of the content.

My study extended these findings to multilinguals and provided more access to the content by offering videos in multiple languages. Hearing the videos in their home/native language promoted a sense of pride and belonging. There were numerous instances of students demonstrating excitement in seeing their home/native language video translation. This enthusiasm translated into increased effort and participation, with most students diligently completing their assignments. This increase in effort and participation compliments other flipped classroom studies' findings (Clark, 2015; de Araujo et al., 2017; Xu et al., 2022; Kuiper et al., 2015; Zhu, 2021). In these studies, the participants were native English speakers and both the language of instruction and the language in the videos was the same. My approach is novel in that regardless of the student's English language proficiency, the content was still readily accessible because it was provided in languages they were already fluent in.

Students initially worked quietly and independently but after implementation of the LAFCM they began to engage in group collaborations, helping one another understand the material and work through the assignments. The classroom became charged with focus and collaboration. The teacher's role shifted to a facilitator, promoting a more collaborative and self-directed learning environment. This shift to collaboration echos other studies on the FCM (Crawford, 2013; de Araujo et al., 2017; Feng, & Chen, 2022; Freeman, 2011; Katsa et al., 2016; Kirvan et al., 2015; Kuiper et al., 2015; Song & Kapur, 2017; Unal et al., 2017; Zhu, 2021), however, once again, these studies only address monolingual classrooms and videos. This study broadened the scope of research to include a multilingual classroom, and videos translated into multiple languages.

Students appreciated the videos being in their native language, the length of the videos, the teacher's explanations, and the note-taking guides. These note-taking guides were designed to mirror what was being covered in the videos so students could easily follow along while taking notes. While previous studies referenced students' preferences for the length of the video and an interactive component to accompany the video (de Araujo et al., 2017; Katsa et al., 2016; Kirvan et al., 2015; Kuiper et al., 2015; Song & Kapur, 2017; Unal & Unal, 2017), they do not explore elements of designing a flipped lesson to appeal to multilingual students. Many students watched the videos multiple times, finding the explanations of sample problems particularly helpful. Previous literature notes students appreciating the ability to rewatch and pause videos (Bhagat et al., 2016; Clark, 2015; de Araujo et al.; Fung, et al., 2021; Graziano & Hall, 2017; Lo, 2017, 2018; Lo & Hew, 2017; Muir, 2015) but provides limited details on what students like or find useful about the videos. The note-taking guides were instrumental in helping students remember and apply the material from the videos during class activities.

The teacher observed increased engagement and noted the benefits of having videos in students' native languages. This study also found students frequently rewatched the videos to understand the material better. This aligns with prior studies on flipped classrooms (Bhagat et al., 2016; Clark, 2015; de Araujo et al.; Fung, et al., 2021; Graziano & Hall, 2017; Lo, 2017, 2018; Lo & Hew, 2017; Muir, 2015), but in this study, students were watching the videos in languages different from the language of instruction used during class. Additionally, students' questions became more content-driven rather than vocabulary-focused. This was a change from the type of questions most students asked prior to the implementation of the LAFCM in this classroom.

Overall, the introduction of multilingual videos and vocabulary mini-lessons marked a turning point in the classroom. Students demonstrated improved understanding, increased confidence, and a stronger sense of agency in their learning. The themes of learning autonomy, peer collaboration, translanguaging processes, pride in use of home language, comprehension and understanding, motivational impact, and confidence in mathematics emerged as significant factors in how multilingual learners used the videos and perceived their impact.

Learning Autonomy: Students took ownership of their learning process by engaging with videos at their own pace, using and referencing their notes and note-taking guides, and rewatching videos to reinforce mathematical concepts. This autonomy was evident in both classroom observations and student reports of their activities inside and outside the classroom.

Peer Collaboration: The use of videos in students' native languages facilitated collaboration among peers, especially in group learning and discussions. Prior to the flipped classroom intervention, students worked primarily independently. However, during the flipped classroom sessions, students worked together in ways that were not previously observed, indicating a shift towards more collaborative learning.

Translanguaging Processes: Students used multiple modes to communicate, drawing on their entire linguistic repertoire to make meaning, communicate effectively, and express themselves fully. This included switching between languages, using gestures, diagrams, pictures, and referencing videos and notes. These translanguaging processes allowed students to engage more deeply with the content and with each other.

Pride in Use of Home Language: Students felt a sense of pride and belonging when their home languages were represented in the classroom. This cultural and linguistic inclusivity fostered a supportive learning environment where students encouraged each other to engage with the material in their native languages.

Comprehension and Understanding: Students reported increased comprehension and understanding of mathematical concepts when they could access content in their native languages. This was evident in their improved participation and willingness to tackle assignments independently.

Motivational Impact: The availability of videos in multiple languages significantly boosted students' motivation and enthusiasm for learning mathematics. The teacher noted increased engagement and preparedness among students, even those who were typically less enthusiastic about classwork.

Confidence in Mathematics: Students demonstrated increased confidence in their mathematical abilities, as seen in their willingness to attempt new problems, explain their thinking, and help others. This confidence was particularly evident during collaborative group activities, where students supported each other and engaged deeply with the content.

These findings highlight the importance of accessibility and language inclusivity in fostering a supportive and engaging learning environment. By providing resources in students' native languages, we were able to enhance their comprehension, motivation, and confidence, ultimately leading to a more collaborative and self-directed classroom dynamic. Prior to the implementation of the Language Accessible Flipped Classroom Model, the classroom was quiet, and students did not collaborate. There were pockets of

students demonstrating understanding of the content and minimal overall student engagement. After the implementation of the first LAFCM, there was more student engagement and on task behavior. Students were observed collaborating and discussing the content in their small groups. After the implementation of the second LAFCM, the entire class was fully engaged in the lesson, and the classroom was abuzz with student discussions and collaboration. This heightened level of engagement is depicted in the *Schematic of LAFCM Before and After* illustrated in Figure 14.

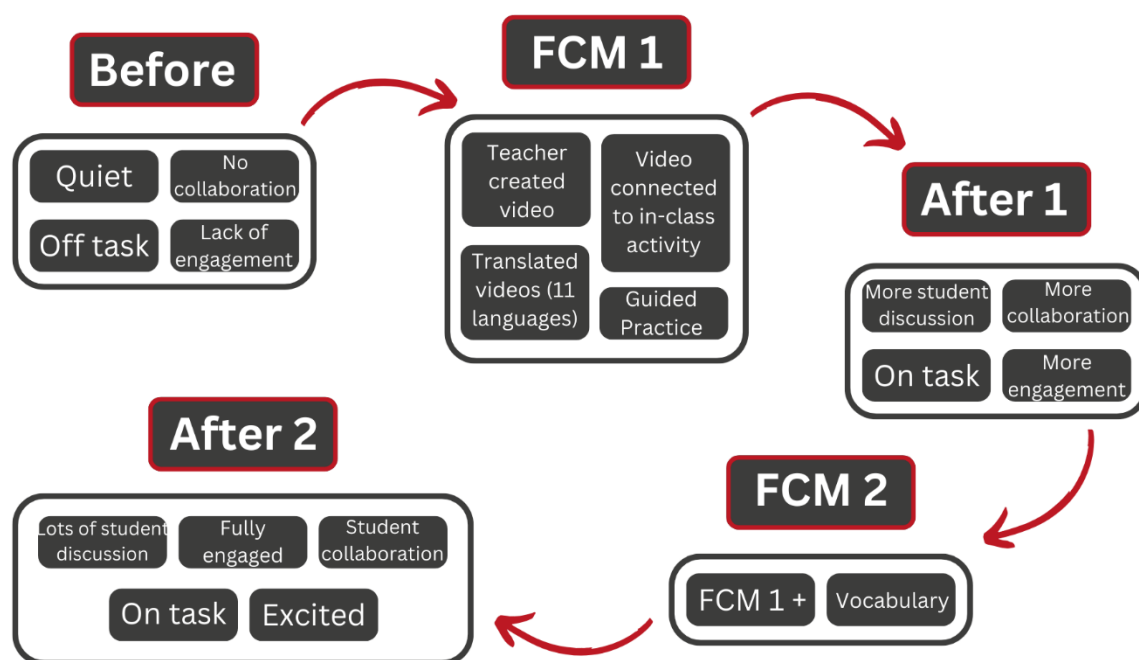


Figure 14

Schematic of LAFCM Before and After

Implications of Research

With the growing advancements in technology and AI assistance in programs, an entirely limitless, new world of possibilities exist for providing access to content for

multilingual students. This study hopes to provide strategies and ideas for leveraging this tool to provide access to multilingual students and educators of multilingual students. Teachers can implement these findings through several practical strategies to enhance student engagement, comprehension, motivation, and confidence. Here are some actionable steps:

1. Incorporate multilingual resources by providing videos in multiple languages.
Create educational videos in students' native languages. This can help them better understand the material and feel more included.
2. Promote learning autonomy by giving students the flexibility to watch videos and review materials at their own pace, enabling them to take control of their learning process. Additionally, provide structured note-taking guides that students can use while watching videos or during lessons. This helps them organize their thoughts and reinforces learning.
3. Facilitate Peer Collaboration by organizing students into small groups to discuss the material and work on assignments together. Encourage them to use their native languages if it helps them communicate more effectively. Encourage students who grasp the material well to help their peers. This not only reinforces their own understanding but also builds a collaborative classroom environment.
4. Support translanguaging practices by encouraging multimodal communication.
Allow students to use a combination of languages, gestures, diagrams, and other visual aids to express their understanding and communicate with peers.

Teacher education programs can play a crucial role in preparing future educators to implement these findings effectively. Here are some suggestions for integrating these insights into teacher education programs:

1. Incorporate multilingual education by including courses on multilingual education and culturally responsive teaching practices. These courses should cover the benefits of using students' native languages in the classroom and provide practical strategies for implementation. Additionally, programs should teach future educators about translanguaging practices and how to create a classroom environment that supports the dynamic use of multiple languages.
2. Offer workshops that focus on creating and using multilingual resources, such as videos, texts, and visual aids. These workshops can also cover how to integrate these resources into lesson plans effectively.
3. Create resource libraries by developing libraries of multilingual resources, including videos, texts, and lesson plans, that student teachers can access and use in their practice.

By integrating these suggestions into teacher education programs, future educators will be better equipped to create inclusive, engaging, and effective learning environments for multilingual learners. This approach not only benefits students but also enriches the teaching profession by fostering a more diverse and culturally responsive educational landscape.

A major implication of these findings is the promotion of equity and access. By providing students videos in their native/home language teachers, schools, districts, and curriculum developers can ensure equitable access to education for all students,

regardless of their linguistic background. This access can help close achievement gaps and promote a more level playing field in mathematics education.

In summary, these findings underscore the importance of language inclusivity and culturally responsive teaching in creating equitable and effective educational environments. By implementing these strategies, educators and researchers can support the diverse needs of multilingual learners and promote their academic success.

Future Research

This study was conducted in one class with one teacher. This research can be expanded to include more classes, teachers, schools, and districts. Research can also be conducted in various content areas to determine if this design is effective in multiple settings and on a broader scale. During this study I noticed Hank's English improving because he was using English more to share his mathematical thinking during class. He also had access to both English and Pashto videos side-by-side, so he was able to get a better understanding of specific words. Hence, I believe more research should be conducted to determine the benefits of the use of this design on language acquisition. Additionally, I think it is important to further explore why it's important for the classroom teacher to create the videos especially for multilingual students. I believe because the students were accustomed to the cadence of speech, accent, and the pronunciation of this particular individual who was their teacher it was easier for them to understand him and the way he speaks versus a random video where they were not used to that dialect or the cadence of the speaker. The study also opens avenues for future research on the impact of multilingual resources and translanguaging in various educational contexts (other contents, grade levels, etc.). This method can also be applied

and studied in other content areas and grade levels. Further research can explore the long-term effects of these strategies on student achievement, engagement, and overall educational experience.

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Appendix A

Teacher Interview Protocol: Pre-Interview

Date: _____
 Time of interview: _____ - _____
 Place: _____
 Interviewee: _____

Introduction

Thank you for agreeing to talk to me today. My name is Jernita Randolph-Bean, and I am a doctoral student in the Department of Mathematics, Science, and Social Studies Education at the University of Georgia. I am conducting a research project on using a flipped classroom model using videos in students' native/home languages. This interview is part of a larger study. Your responses will help provide insight into the use of flipped videos and lesson activities in an Algebra Concepts and Connections class. This interview will be recorded and should take about 45 minutes. That said, everything that you say is confidential. Before we begin, I would like to remind you that if I ask any questions that you would rather not answer, please say so and I will gladly move on to a different question. There are no right or wrong answers. Do you have any questions before we begin?

1. What is your name?
2. How long have you been teaching?
3. How long have you been working with multilingual students?
4. What are some of the assets and challenges that multilingual students have/face?
5. What do you find rewarding about working with multilingual students?
6. What are the challenges that you have found while working with multilingual students?
7. What curriculum materials have you used to teach the Algebra Concepts and Connections course?
8. If you have used the Georgia Department of Education Instructional Learning Plans, how do you determine which ones to use? How do you use them?
9. Do you modify materials for your multilingual students? If so, how?
10. What curriculum materials do you find best suited for teaching multilingual students?
11. Do you use content videos as a resource for your students? If yes, what kind of videos? (*Probe: Khan Academy, textbook, teacher created, etc.*) How do you use them? How often do you use them?
12. Do you use any instructional platforms/materials? (*Probe: EdPuzzle, PearDeck, PlayPosIt, Desmos, Geogebra, etc.*) How do you use them?
13. Do you use collaborative groups? If yes, how do you determine the groups? How often do you use collaborative groups?
14. Describe a typical instructional block in your class.
15. How would you define a flipped classroom?
16. Have you ever "flipped" your classroom? If yes, what did it look like?

Before we complete this interview, is there anything you would like to add before we end? Do you have any questions for me? Thank you once again for participating in this interview.

Appendix B

Student Interview Protocol: Pre-Interview

Date: _____
 Time of interview: _____ - _____
 Place: _____
 Interviewee: _____

Introduction

Thank you for agreeing to talk to me today. My name is Jernita Randolph-Bean, and I am a doctoral student in the Department of Mathematics, Science, and Social Studies Education at the University of Georgia. I am conducting a research project on using a flipped classroom model using videos in students' native/home languages. This interview is part of a larger study. Your responses will help provide insight into the use of flipped videos and lesson activities in an Algebra Concepts and Connections class. This interview will be recorded and should take about 45 minutes. That said, everything that you say is confidential. Before we begin, I would like to remind you that if I ask any questions that you would rather not answer, please say so and I will gladly move on to a different question. There are no right or wrong answers. Do you have any questions before we begin?

1. Where were you born?
2. Have you lived in places other than here?
3. What is your home/native language?
4. What languages do you speak?
5. How long have you been speaking English?
6. How old are you?
7. Have you ever had to stop going to school for a period of time (interruptions in schooling)? If yes, for how long?
8. Do you think math is easy? hard?
9. Do you prefer to work on math alone or with partners?
10. Have you ever watched videos that explain a mathematical concept?
 - a. Did you watch the whole video? If not, why did you stop watching the video?
 - b. Were you able to learn from the video?
 - c. What did you like about the video?
 - d. What would you change about the video?
11. Do you take notes in class?
12. Do you take notes when you watch a video?
13. Do you use notes to help you solve problems?
14. What do you do when you do not understand something in math?
15. What activities do you like to do in your math class?
16. What do you think helps you understand how to work problems in your math class?

Before we complete this interview, is there anything you would like to add before we end?
 Do you have any questions for me? Thank you once again for participating in this interview.

Appendix C

Teacher Interview Protocol: Post-Flipped Lesson-Interview

Date: _____
 Time of interview: _____ - _____
 Place: _____
 Interviewee: _____

Introduction

Thank you for agreeing to talk to me today. My name is Jernita Randolph-Bean, and I am a doctoral student in the Department of Mathematics, Science, and Social Studies Education at the University of Georgia. I am conducting a research project on using a flipped classroom model using videos in students' native/home languages. This interview is part of a larger study. Your responses will help provide insight into the use of flipped videos and lesson activities in an Algebra Concepts and Connections class. This interview will be recorded and should take about 45 minutes. That said, everything that you say is confidential. Before we begin, I would like to remind you that if I ask any questions that you would rather not answer, please say so and I will gladly move on to a different question. There are no right or wrong answers. Do you have any questions before we begin?

1. What are your thoughts about the flipped lesson?
2. What were some benefits of flipping your class?
3. What were some challenges to flipping your class?
4. What adjustments would you make to the lesson?
5. Did you notice students using any information from the videos in their class engagement?
6. Did you notice any changes in students' engagement in small group discussions?
7. Did you notice any changes in students' engagement in whole group discussions?
8. Do you have any suggestions for future flipped lessons?

Before we complete this interview, is there anything you would like to add before we end? Do you have any questions for me? Thank you once again for participating in this interview.

Appendix D

Student Interview Protocol: Post-Flipped Lesson-Interview

Date: _____
 Time of interview: _____ - _____
 Place: _____
 Interviewee: _____

Introduction

Thank you for agreeing to talk to me today. My name is Jernita Randolph-Bean, and I am a doctoral student in the Department of Mathematics, Science, and Social Studies Education at the University of Georgia. I am conducting a research project on using a flipped classroom model using videos in students' native/home languages. This interview is part of a larger study. Your responses will help provide insight into the use of flipped videos and lesson activities in an Algebra Concepts and Connections class. This interview will be recorded and should take no longer than 45 minutes. That said, everything that you say is confidential. Before we begin, I would like to remind you that if I ask any questions that you would rather not answer, please say so and I will gladly move on to a different question. There are no right or wrong answers. Do you have any questions before we begin?

1. Did you watch the flipped video(s)?
2. Which version of the video did you watch? If both, in what order?
3. Did you watch the whole video? If not, why did you stop watching the video?
4. Did you pause the video/ rewind/ rewatch the video?
5. What did you learn from the video?
6. What did you like about the video?
7. What would you change about the video?
8. Did you take notes while you watched the video?
9. Did you use notes to help you solve problems?
10. Did you understand the information in the videos? If not, what didn't you understand and did you receive help to understand the information?
11. What activities did you like about the flipped lesson?
12. What activities would you change about the flipped lesson?
13. How confident do you feel about the material after watching the video(s)?
14. How confident do you feel about working on problems with other students during class?
15. Has watching the video(s) made you want to work on problems in class more? Less? Or about the same? Why do you believe that is?

Before we complete this interview, is there anything you would like to add before we end? Do you have any questions for me? Thank you once again for participating in this interview.

Appendix E

Focus Group Interview Protocol

Date: _____
 Time of interview: _____ - _____
 Place: _____
 Interviewee: _____

Introduction

Thank you for agreeing to talk to me today. My name is Jernita Randolph-Bean, and I am the moderator for today's focus group session. The purpose of this focus group is to understand your perspectives on the flipped videos and lesson activities that you participated in during your Algebra class. This interview will be recorded and should take about 60 minutes. That said, everything that you say is confidential. I ask that you do not share what others have discussed with people outside of this group.

Ground Rules

Before we begin, I would like to remind you that if I ask any questions that you would rather not answer, please say so and I will gladly move on to a different question. There are no right or wrong answers. I am interested in your opinions and perspectives on the flipped videos and the lesson activities from (*insert date of class*). You do not have to agree with everyone else in this room if that is not how you really feel. I expect that you may have different views on these questions. I want you to feel comfortable saying good things as well as critical things. I am not here to promote a particular way of thinking. I just want to understand your thoughts about the lesson. During the interview, I ask that you speak one at a time and in a clear voice. If you have a mobile device, please place it on silent at this time. Do you have any questions before we begin?

1. Describe your flipped lesson experience.
2. Did the video lesson help prepare you for the in-class activity? How was it useful?
 (Probing questions: *For instance, did you use notes from the video to help you with the in-class activity? Did the guided practice problem (s) make it easier for you to do the in-class activity?*)
3. How did you work on the in-class activity? (Probing questions: *For instance, did you work on the in-class activity as a group, with partners, or individually? Did everyone in the group work on the activity and then you discussed your answers or did you all work together on each of the problems? Did you need the teacher's help to do the in-class activity? Did you work with another group? Did you re-watch the video in class to help you with the in-class activity?*)
4. What did you find helpful about the video? How was it helpful?
5. What would you change about the video? Why?
6. Would you like to have access to more videos in your native/home language?

I may use video clips of the small group working on the learning activity from the flipped lesson as a focusing exercise and ask clarifying questions about the in-class activities. An example of a video clip would be instances where students refer to the content of the videos while working in class. This would provide an opportunity to probe into the specifics of the use of the video. Questions might include: *Did you use notes from the video to help you with... (address the content of the video clip)? Did the guided practice problem (s) make it easier for you to... (address the content of the video clip)? You said/wrote/gestured... Do you mind explaining what does it mean?*

Closing

Thank you so much for taking the time to talk to me and share your flipped classroom experiences. Is there anything else that you would like to share that we have not covered? Do you have any questions for me? Once again, thank you for your participation in this focus group.

Appendix F



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Multiplying Binomials and Factoring Trinomials

Solving Puzzles

Puzzle #1:

		3
10		30
4	80	

Puzzle #2:

	100	30	2
20		600	
2			

Puzzle #3:

	x	
10x		
4		12

Puzzle #4:

		2
	$3x^2$	$6x$
		-2

Puzzle #5:

	$2x^2$	$-3x$	2
x			
-2			

Puzzle #6:

	$2x^2$	
		-5

Multiplying and Factoring

Section 1: Multiply the following polynomials.

- Multiply $(x - 3)(3x + 1)$.
- A rectangle has side lengths of $(x + 2)$ and $(x - 1)$. Write an expression that represents the area of the rectangle.

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3. Multiply $2x$ and $-x^2 - 3x + 2$.

4. What is the product of $(4x + 2)$ and $(3x - 1)$?

Section 2: Factor the following polynomials.

1. What is the factored form of $x^2 + 10x + 21$?

2. What are the factors of the trinomial $x^2 + 7x - 18$?

3. What two binomials have the product of $2x^2 + 5x - 3$?

4. The area of a rectangle is represented by the expression $3x^2 + 10x + 7$. What are the length and width of the rectangle?

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Extra Practice

Section 1: Area models for multiplication

1. If the sides of a rectangle have lengths $x + 3$ and $x + 5$, what is an expression for the area of the rectangle? Draw the rectangle, label its sides, and indicate each part of the area.
2. For each of the following, draw a rectangle with side lengths corresponding to the factors given. Label the sides and the area of the rectangle:

a. $(x + 3)(x + 4)$	b. $(x + 1)(x + 7)$
c. $(x - 2)(x + 5)$	d. $(2x + 1)(x + 3)$

Section 2: Factoring by thinking about area and linear quantities

For each of the following, draw a rectangle with the indicated area. Find appropriate factors to label the sides of the rectangle.

- | | |
|--------------------|--------------------|
| 1. $x^2 + 3x + 2$ | 2. $x^2 + 5x + 4$ |
| 3. $x^2 + 7x + 6$ | 4. $x^2 + 5x + 6$ |
| 5. $x^2 + 6x + 8$ | 6. $x^2 + 8x + 12$ |
| 7. $x^2 + 7x + 12$ | 8. $x^2 + 6x + 9$ |
| 9. $x^2 + 4x + 4$ | |

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Timing a Fountain

A civic engineer is planning a park for Atlanta. He must choose between two different fountain designs that shoot out drops of water. The nozzle on Fountain A from which the water is launched is 4 meters above the ground. It shoots out a drop of water at a vertical velocity of 8 meters per second. The nozzle on Fountain B from which the water is launched is shoots out a drop of water whose height can be represented by the equation $b(x) = -(5x + 2)(x - 1)$.

1. Let the function $a(x)$ model the height of the water that Fountain A shoots from the nozzle. If the function is defined by $a(x) = -5t^2 + v_0t + h_0$ where v_0 is the vertical velocity from which the water is launched and h_0 is the initial height of the water, write a function, $a(x)$ that models the height of water from Fountain A.
2. If the engineer wants the water that shoots from the nozzle to be in the air for a minimum of 1.5 seconds, which Fountain should they choose? Explain or show how you made your decision.
3. The engineer changed his mind! Now they want a fountain that has water that starts at a maximum height of 3 meters. Which fountain should the engineer choose? Explain or show how you made your decision.

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Formative Assessment

What is the factored form of $6x^2 + 11x - 35$?

What is the standard form of $(4x - 2)(x + 8)$?

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Appendix G



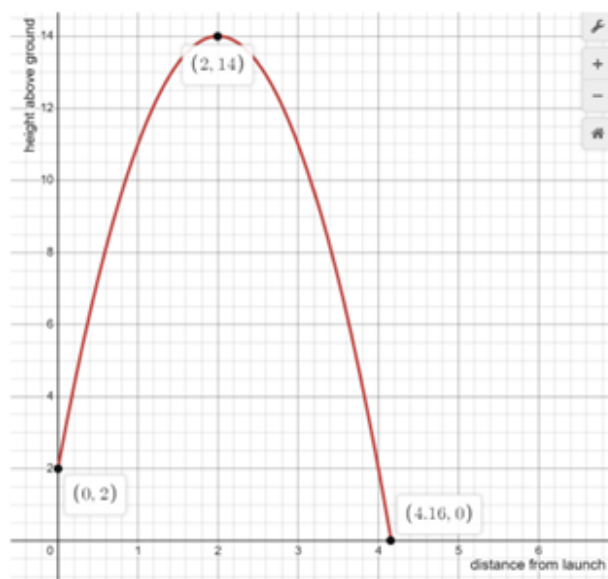
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Characteristics of Quadratic Functions**Diagnostic Assessment**

1. Label the following characteristics on the graph: a) vertex, b) y-intercept, c) x-intercept, d) maximum/minimum.
2. Write a story or scenario that can be represented by the graph below.



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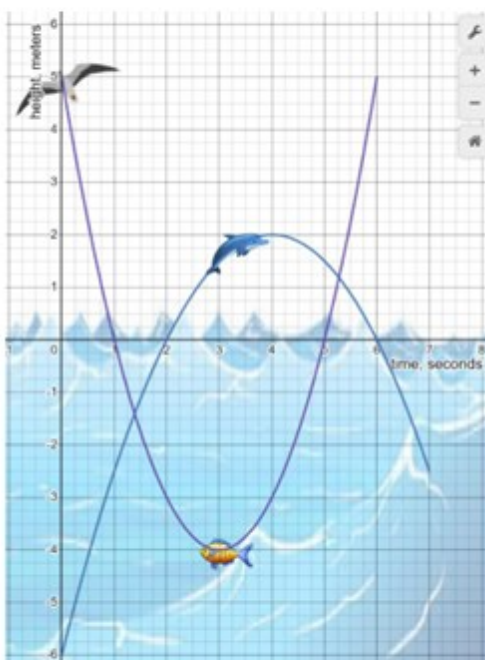


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An Oceanic Story



x	0	1	2	3	4	5	6	7
B(x)	5	0	-3	-4	-3	0	5	n/a
D(x)	-6	-2.5	0	1.5	2	1.5	0	-2.5

A beachgoer is observing the ocean from afar. They observe a bird diving into the water to get a fish and a dolphin jumping out of the ocean. Let $D(x)$ define the path of the dolphin and $B(x)$ define the path of the bird. Use the graphs and table shown above to explore and define various **key features** of parabolas.

1. The **vertex** of a parabola is the point on a parabola that intersects the axis of symmetry. This is where the parabola changes direction. The vertex for $D(x)$ is (4, 2). The dolphin reaches a maximum height of 2 meters 4 seconds after the beachgoer begins watching. What is the vertex of $B(x)$ and what does this point mean in context? Is this a maximum or minimum?

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2. The **x-intercepts (or zeros)** of a function are the point(s) where the function crosses or touches the x-axis, or where $y = 0$. The x-intercepts of $B(x)$ are $(1, 0)$ and $(5, 0)$. This means that the height of the bird above sea level was 0 meters after 1 second and 5 seconds. What are the x-intercepts of $D(x)$ and what do these points mean in context?

3. The **y-intercept** of a function is the point that crosses the y-axis. This is also called the initial value. The y-intercept of $D(x)$ is $(0, -6)$. This means that the dolphin was 6 meters below sea level when the beachgoer begins watching. What is the y-intercept of $B(x)$ and what does this point mean in context?

4. The **intervals of increase and decrease** are the intervals of x-values where the function is either increasing or decreasing. Function $D(x)$ has an interval of increase when $0 \leq x < 4$ because the dolphin's height is going up between 0 and 4 seconds. The interval of decrease of $D(x)$ is $4 < x \leq 7$ because the height of the dolphin is going down between 4 seconds and 7 seconds (when the dolphins jump is over). What are the intervals of increase and decrease for $B(x)$? What do they tell us about the path of the bird?

5. **Domain** and **Range** describe all of the possible inputs and outputs of a function. Domain describes inputs, or x-values, and range describes outputs, or y-values. The domain of $D(x)$ is $0 \leq x \leq 7$ (0 to 7 seconds); the range of $D(x)$ is $-6 \leq y \leq 2$ (6 meters below sea level to 2 meters above sea level). What are the domain and range of $B(x)$?

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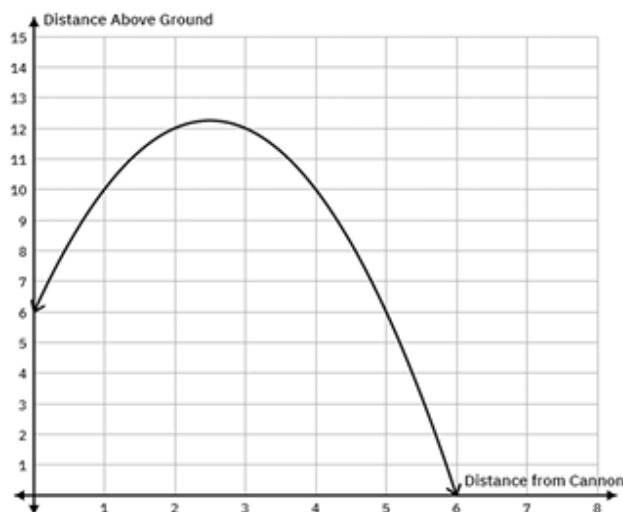
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This Launch is Bananas

A banana is launched from a slingshot into the air from a cliff. The path of the banana is shown below by function $b(x)$. Work with a partner to decide if each statement about the path of the banana is true or false. Be prepared to defend your answers. All measurements are given in feet.



Distance from Cannon	Distance above Ground
0	6
1	10
2	12
3	12
4	10
5	6
6	0

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True	False

1. Justify your thinking for statement B. Explain how you knew this statement was true or false.
2. Justify your thinking for statement F. Explain how you knew this statement was true or false.
3. Justify your thinking for statement K. Explain how you knew this statement was true or false.
4. Choose one other statement to justify. Explain how you knew if the statement was true or false.

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Formative Assessment Questions

1. Determine the a) domain b) range c) interval increase d) interval of decrease of the below graph and explain what they mean in the context of the story you wrote in the Diagnostic Assessment.



2. Use the table below to determine the vertex, the y-intercept, and the x-intercepts of the function.

x	-2	-1	0	1	2	3	4
f(x)	6	3	2	3	6	11	18

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Statements for the “This Launch is Bananas” Task

A. The y-intercept of $b(x)$ is $(0, 6)$.	B. $b(4) = 10$	C. The vertex of the function is at $(3, 12)$.
D. The height of the banana is decreasing on the interval $2.5 < x \leq 6$.	E. The banana reaches a maximum height of approximately 12.25 feet.	F. The banana is launched from a cannon 6 feet above the ground.
G. The interval of increase of the function is $0 < x < 4$.	H. When the banana is 5 meters from the cannon, it is 8 meters above the ground.	I. The banana has reached the same height as the cannon when it was 5 feet away from the cannon
J. $b(x)$ has a domain of $0 \leq x \leq 6$.	K. The banana reaches the ground 5 feet from the cliff.	L. The function has an axis of symmetry at $x = 2.5$.

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UNIVERSITY OF GEORGIA**CONSENT FORM****Teaching Mathematics to Multilingual and Multicultural Learners in a Secondary Mathematics Classroom Using the Flipped Classroom Model****Researcher's Statement**

You are being asked to take part in a research study. Before you decide to participate in this study, it is important that you understand why the research is being done and what it will involve. This form is designed to give you the information about the study so you can decide whether to be in the study or not. Please take the time to read the following information carefully. Please ask the researchers if there is anything that is not clear or if you need more information.

Principal Investigator:

Dr. Annamarie Conner, Professor
Department of Mathematics, Science, and Social Studies Education
University of Georgia
105 Aderhold Hall
Athens, GA 30602
Email: aconner@uga.edu

Purpose of the Study

The purpose of this study is to investigate the impact of the FCM on multilingual students and determine effective strategies for designing flipped classroom instructional materials that cater to the unique needs of diverse learners in a secondary algebra classroom.

Study Procedures

If you agree to participate, you will be asked to participate in both individual and focus group interviews. There will be three individual interviews and two focus group interviews. This investigation will also involve observing your activities in class and video recording your discussions. You should know that samples of your work may be made public as part of the researchers' scholarly presentations and/or publications (dissertation, journals). All samples of student work will be stripped of personal identifiers. Further, your consent to participate is confidential and voluntary. This work will have no bearing on your performance assessment at school. If you are interested in participating in the study, please read the additional information on the following pages, and feel free to ask questions at any point.

Audio/Video Recording

Videos recorded in the class and other data will be used for the study. These recordings are needed to explore the interactions between students and teachers during

instruction. These recordings will not have identifiable information. These recordings will be archived and destroyed after 5 years.

Risks and discomforts

There are no risks involved in this study.

Benefits

A potential benefit is access to class content in your native/home language.

Privacy/Confidentiality

All data will be kept confidential. Only the researchers on this project will have access to the data. The paper records of data will be locked in a file cabinet and video records will be stored on a password-protected computer. All identifying information will be removed from both paper and video data. To do this, researchers will link a pseudonym to the study participants. Only the researchers will have access to the data and pseudonym code key. The results of the research study may be published, but indirect identifiers or codes will be used. This means pseudonyms will be used and the blurring of faces on video data will be done to ensure there is no identifiable student information. Further, researchers will not release identifiable results of the study to anyone other than individuals working on the project without your written consent unless required by law.

Participant rights

Your involvement in the study is voluntary, and you may choose not to participate or to stop at any time without penalty or loss of benefits to which you are otherwise entitled. If you have any questions or concerns regarding your rights as a research participant in this study, you may contact the Institutional Review Board (IRB) Chairperson at 706.542.3199 or irb@uga.edu.

If you agree to participate in this research study, please sign below:

_____	_____	_____
Name of Researcher	Signature	Date
_____	_____	_____
Name of Participant	Signature	Date

Please keep one copy and return the signed copy to the researcher.

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Risks and discomforts

There are no risks involved in this study.

Benefits

A potential benefit of this study will be the creation of instructional videos in your students' native/home language(s).

Privacy/Confidentiality

All data will be kept confidential. Only the researchers on this project will have access to the data. The paper records of data will be locked in a file cabinet and video records will be stored on a password-protected computer. All identifying information will be removed from both paper and video data. To do this, researchers will link a pseudonym to the study participants. Only the researchers will have access to the data and pseudonym code key. The results of the research study may be published, but indirect identifiers or codes will be used. This means pseudonyms will be used and the blurring of faces on video data will be done to ensure there is no identifiable student information. Further, researchers will not release identifiable results of the study to anyone other than individuals working on the project without your written consent unless required by law.

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