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AP Statistics Students' Conceptions of Engagement and Technology in a Flipped Classroom: A Phenomenographical Study

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By

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Dedication

I dedicate this to my husband, Dr. Curtis Gile (Scott), and daughter, Dalayla Gile. I have spent the better part of four years in a book or working. You both have been patient, loving, and supportive of this process. Scott, you have been through a doctorate and encouraged me. You have said you were proud of me more times than I can count. I would not have been able to complete this degree without your support and understanding. I cannot wait for the journey we have ahead sharing the house chores again and enjoying golf carting on the weekends together. Dalayla, you have surprised me by cleaning the house, getting me pedicures, and bringing me treats. You have had patience even though "Mom is always working." I love you both more than words can express.

I would also like to dedicate this work to my parents, Carol and Cole Colter. They instilled in me a great work ethic. The expectations of college education for their children and backing it up by giving their children a college education with no student debt gave all of us a solid base to start life. Their example of going to college while raising a family and holding down full-time jobs showed me, I was capable of all things. Thank you so much for your support, love, and the example you have set. Love you both.

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Abstract

The purpose of this dissertation was to study student engagement and disengagement within an AP Statistics course using flipped classroom strategies. Vygotsky's Zone of Proximal Development and Scaffolding, Dewey's Active Learning Theory, the Microsystem of Student Engagement in a Flipped Classroom, and the Framework for Engagement with Mathematics were the theoretical foundation for this study. A phenomenographical methodology was followed to answer the question: How do AP Statistics students experience engagement in the flipped classroom? as well as the sub questions: Which learning experiences help to engage students and why? And which learning experiences contribute to student disengagement and why? Data was collected through student interviews and journals. Interviews were analyzed phenomenographically, and student journals were analyzed using thematic analysis. This analysis was done iteratively as a whole and in parts to establish categories of description, which developed an outcome space to form the students' conceptions of engagement. This outcome space included social, cognitive, and affective dimensions of engagement; students' internal motivation was also included. Student journals supported elements of the outcome space. This study also found elements of student affective, cognitive, and behavioral disengagement. Social engagement was coded the most often in student interviews and journals. Students' engagement came from collaborative, active learning activities and projects. These findings helped address the lack of studies in K-12 settings on social engagement, especially in a secondary math classroom and support that engagement is a multi-dimensional construct with behavioral, affective, cognitive, and social dimensions, with social engagement being the most important to students. Teachers should actively engage students in classroom activities that allow them to work with their peers, incorporate technology, and provide them with choices and opportunities

to apply the knowledge they learned with authentic real-world activities. Moreover, statistics teachers can engage students by providing opportunities for students to collect and use data in learning. Future directions for research are also discussed.

Keywords: active learning, affective disengagement, affective engagement, AP Statistics, behavioral disengagement, behavioral engagement, cognitive disengagement, cognitive engagement, flipped learning, phenomenography, social engagement, student disengagement, student engagement

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Chapter One: Introduction

Student disengagement is a great concern for high school teachers as students report that being disengaged in school increases drastically at that age. Gallup (2017), a research agency, polled 915,214 United States students from 50 states on engagement based on nine factors: doing what they do best, feeling schoolwork is important, feeling safe, having fun, having a best friend, doing good work, learning something interesting, feeling adults care, and having excitement for the future. Gallup's poll found that 74% of all fifth-grade students report being engaged in school, and only 34% of twelfth-grade students report engagement in school. A study with over 21,000 high school students found that responses to questions about their feelings about school were primarily negative (Moeller et al., 2020). When asked to describe their feelings at school, students reported negative emotions such as tiredness, stress, boredom, anxiety, annoyance, sadness, loneliness, and depression (Moeller et al., 2020). Students entering high school with these negative feelings about school may lack engagement in school and classroom activities (Moeller et al., 2020). Moreover, these disengaged students have behavioral and academic difficulties in school, and they may act out by disrupting learning in the classroom, skipping classes, and not engaging in class activities or assignments (Newmann, 1992). They often show little "excitement, commitment or pride in the mastery of the curriculum" (Newmann, 1992, p. 2) and do not have meaningful long-term learning because of disengagement in class (Schlechty, 2011). Actively disengaged students are around seven times more likely to be discouraged and report receiving bad grades nine times more than their engaged peers (Gallup, 2017). All these adverse behavioral and academic outcomes for actively disengaged students make it essential for teachers to create a learning environment that engages students.

One pedagogical method shown to improve engagement in the classroom is a flipped learning model (Attard, 2014; Attard & Holmes, 2020b; Bergmann & Sams, 2012). The flipped classroom approach provides teachers more time to provide engaging, active, collaborative learning activities (Kostaris et al., 2017). Student engagement has been widely accepted as a multidimensional construct, including behavioral, affective, and cognitive aspects (Fredricks et al., 2004). Another construct of engagement that has been noticed recently, but less studied is social engagement. This study will look at all four dimensions of engagement– behavioral, cognitive, affective aspects of engagement (Fredricks et al., 2004), and social engagement (Fredricks et al., 2016; Linnenbrink-Garcia et al., 2011). This study seeks to use qualitative phenomenographical methods to capture AP Statistics high school students' voices and perspectives to find which elements and teaching strategies of the flipped classroom engage them and why.

This chapter will include background on the flipped classroom and a theoretical framework that frames this study. It begins with a discussion of the origins of the flipped classroom and the structure of classroom time to increase active learning. The problem statement and the research questions are presented. The chapter ends with the study's theoretical framework related to the flipped classroom, the definition of engagement, the four dimensions of the construct of engagement, and the definition of terms often used in the study.

Background

The origins of the flipped classroom start with classrooms in the early 2000s and were developed to include more active learning in the classroom. Lage et al. (2000) were early adopters of the inverted classroom. College instructors provided VHS tapes and the university's television station broadcast video lectures to students outside of class to allow for more active

learning during class time (Lage et al., 2000). Bergmann and Sams (2012), two chemistry teachers from Woodland Park, CO, were the first to coin the term flipped classroom. They created videos for students to have direct instruction outside the class and provided active learning opportunities during class (Bergmann & Sams, 2012). The purpose of this teaching method was for teachers to maximize class time to increase student engagement (Attard & Holmes, 2020b). These originators of the flipped classroom used teaching models that moved away from traditional lectures in class to maximize classroom time for students to have active learning experiences.

Traditional teaching methods focus on students having classroom lectures and doing homework at home, but the flipped learning environment transforms the classroom into an interactive learning space with a teacher as the guide. The teacher-guided group learning space is meant to be an interactive environment (Flipped Learning Network, 2014b). Active learning prevents students from being in a classroom dominated by passive learning where the teacher is the expert (Freeman et al., 2014) and is fundamental to all aspects of student engagement (Barkley & Major, 2020). Flipped learning classroom time is used to implement scaffolded hands-on, active student learning (Bergmann & Sams, 2012; Kostaris et al., 2017). During active learning, students participate in higher-order thinking processes (Freeman et al., 2014). Flipped learning maximizes the time for active learning which allows for a student-centered classroom where students reach higher-order thinking processes collaboratively and are engaged in learning.

Problem Statement

This research focused on a high school AP Statistics classroom using the flipped classroom model to increase students' active learning time in statistical concepts due to the

limited number of classroom hours to teach before the exam. The research location was a large high school in the south where the researcher was employed. At this location, AP Statistics was offered in a one-semester format during the second semester, which includes about 113 hours of course instruction. Lee and Harrison (2021) reported that 75% of AP Statistics courses are taught in either a 90-minute block for half the school year or a 45- to 60-minute class period lasting all year. So, other teachers face the same challenges to teach AP Statistics in a condensed format. The students must learn the entire AP Statistics curriculum in fifteen weeks of school because the AP Exam is given in early May each year, which causes three weeks of loss of instruction for the semester. Students must be engaged with learning to meet the time constraints, learn rigorous material, and prepare for the AP Statistics exam at the end of the course while retaining the content they learned.

The relatively early administration of the AP Statistics test encourages teachers to deliver the content forthrightly, and teachers can sometimes default to lectures when pressed for time as it is the most direct form of instruction. In a study by Lee and Harrison (2021), although statistics teachers knew that active learning was best and felt like they were teaching with activities, students felt their teachers presented content through lectures. Research shows the primary mode of instruction in statistics should not be lectures (Cobb, 1992; Lee & Harrison, 2021). The essence of engagement is when students are not passively learning but instead actively involved in learning (Mercer et al., 2021). AP Statistics students must actively collect data, work with data, and come to conclusions from data. Active learning, or learning by doing, is often accomplished with simulations, discovery, project-based learning, and well-structured hands-on activities (Neebe & Sikora, 2022). Statistics learning should be constructive, where students learn by doing with an instructor to give feedback (Cobb, 1992). A flipped classroom model can

maximize active, collaborative learning time because passive, direct instruction occurs outside the classroom (Attard & Holmes, 2020b).

Current research has studied different aspects of the flipped classroom. Existing research on the flipped classroom has examined academic performance (i.e., Graziano & Hall, 2017; Pardimin et al., 2022; Spotts & Gutierrez de Blume, 2020; Torres-Martin et al., 2022; Unal & Unal, 2017); student motivation (i.e., Conner, 2021; Katsa et al., 2016; Kostaris et al., 2017; Muir, 2018); and cognitive learning outcomes (i.e., Katsa et al., 2016; Kostaris et al., 2017; Zupanec et al., 2022). However, research that studies engagement in the flipped classroom at a high school level is lacking.

The studies that have researched student engagement in a flipped classroom differ in their focus on the dimension of engagement studied. Hodgson et al. (2017) only researched behavioral engagement in the flipped classroom. Three other studies clearly defined engagement as a multidimensional construct with the three dimensions of engagement – emotional, cognitive, and behavioral. Two of these studies studied the flipped math classroom in high school– Algebra and Pre-Calculus classes (Cevikbas & Kaiser, 2021; Lo & Hew, 2020). The other study was done in an English class (Aycicek & Yelken, 2021). Only one of the three studied all four dimensions of engagement– affective, cognitive, behavioral, and social in a biology course (Wilson, 2021). None of these studies on flipped classroom engagement were conducted in a high school statistics course. The focus of this study on all four dimensions of engagement in an AP Statistics flipped classroom is lacking in literature.

Current research on engagement in the flipped classroom uses many methodologies to study engagement. The methods used are quasi-experimental (i.e., Aycicek & Yelken, 2021; Bhagat et al., 2016; Spotts & Gutierrez de Blume, 2020; Torres-Martin et al., 2022; Unal &

Unal, 2017; Zupanec et al., 2022), mixed methods (i.e., Conner, 2021; Graziano & Hall, 2017; Hodgson et al., 2017; Muir, 2018; Pardimin et al., 2022; Wilson, 2021), or action research (i.e., Katsa et al., 2016; Kostaris et al., 2017). Bond et al. (2020) found that these were the primary methodologies in their metanalysis research on engagement and educational technology. Student engagement has been studied using all these methods, but pure qualitative methodologies are rare, especially phenomenographical studies. Therefore, there is a need to understand engagement from a student's perspective with a qualitative study that gives participants a voice to discuss their perspectives on teaching methodology, the technology used, and active learning lessons.

Purpose of the Study

This phenomenographical research aims to explore AP Statistics students' varied lived experiences of behavioral, affective, cognitive, and social engagement in the AP Statistics course using a flipped classroom approach. This study seeks to give students a voice to understand the learning experiences that engage and disengage them in the classroom. The results will contribute to finding effective strategies, activities, technology tools, or design features for a high school math classroom that sustain student engagement in statistics courses using the flipped classroom method and support the expanded construct of engagement to include social engagement.

Research Questions

Question: How do AP Statistics students experience engagement in the flipped classroom?

Sub-question #1: Which learning experiences help to engage students and why?

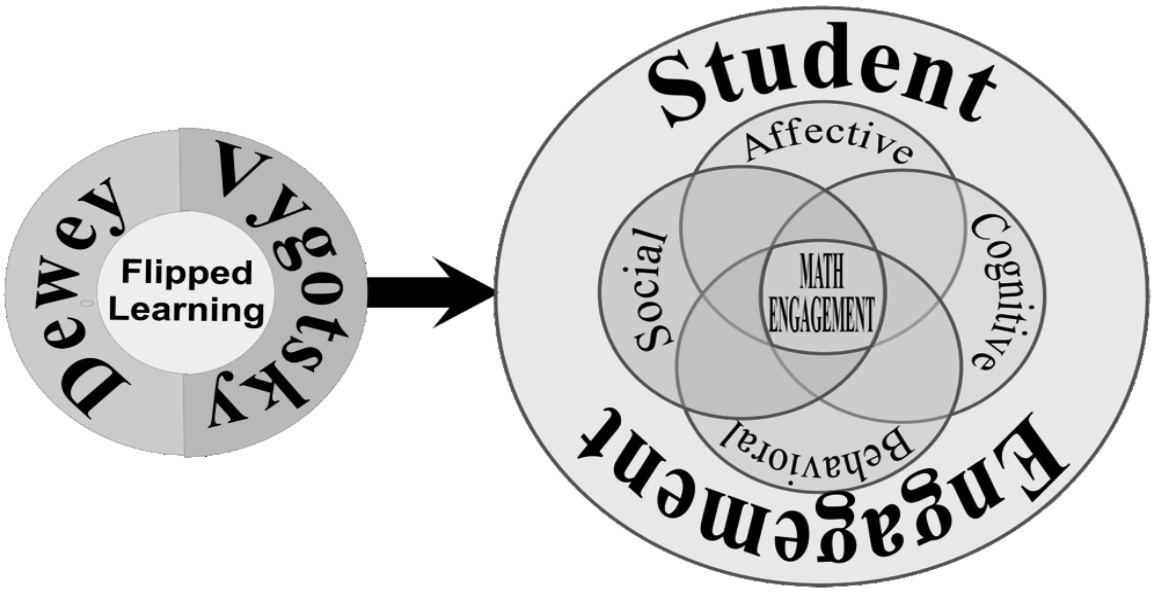
Sub-question #2: Which learning experiences contribute to student disengagement and why?

Theoretical Framework for the Study

The theories used to inform this study are Vygotsky's zone of proximal development (1978) and Dewey learn by doing theories (1916, 1938), Bond and Bedenlier's Student Engagement Framework (2019), and Attard and Holmes' (2020b) Framework for Engagement with Mathematics (FEM). Vygotsky's (1978) and Dewey's (1916, 1938) learning theories support the structure of active learning in the flipped classroom (see Figure 1). Bond and Bedenlier (2019) and Attard and Holmes (2020b) define engagement frameworks with technology and mathematics. The following section will present each theory and how it relates to the flipped classroom and student engagement within the context of this study.

Figure 1

Theoretical Framework for this Study



Theories of Learning

Constructivist learning theories suggest that learners are active participants in their learning. Constructivists posit that when people experience the world and reflect on their experiences and interactions with people, they construct their own beliefs and knowledge of the world (Harasim, 2017). The flipped classroom model exemplifies the constructivist learning model, using collaborative learning exercises where students can help their peers internalize learning and move students through a zone of proximal development (Ouda & Ahmed, 2016). With this classroom structure in mind, it is evident that learning theories from John Dewey and Lev Semyonovich Vygotsky are compatible with the learning structure of the flipped classroom.

John Dewey's Learning Theories

Dewey was an educator and philosopher who sought to reform education. Dewey (1938) spoke out against traditional learning. Although Dewey was a pragmatist, his theories foreshadowed constructivists' social and active learning theories. Dewey (1938) believed that traditional educators considered students as passive learners who were receptive to learning without questioning the teacher. Students were meant to be compliant and absorb concepts. Dewey (1938) believed traditional learning models were teacher-led, and the subject matter taught was deemed necessary by adults. The students struggled with learning gaps due to a lack of maturity to understand the material or the behavior expected by traditional education. Dewey (1938) disliked traditional teaching methods where the students were not given choices and were expected to learn without input to their learning.

Dewey spoke against the traditional education model, but he also spoke out against the current progressive education as well. Dewey (1938) believed progressive educators only chose their teaching method to be the opposite of traditional teaching. In progressive schools, guidance from adults was seen as interfering with a student's freedom. The learning environment seemed chaotic, as students were not mature enough to choose topics without guidance from an adult (Dewey, 1938). Dewey believed progressive schools needed to be more organized and guide students' studies. Both the progressive and the traditional forms of schooling did not give students what they needed to be productive members of society.

Dewey (1938) proposed a method that landed somewhere between these two extreme teaching methods. He believed that students should not be passive learners in the traditional classroom, nor should they have all the freedoms given to them in the progressive classroom. There needed to be a balance of both methods to engage students. Dewey (1916) believed that

students should be engaged in learning activities that held interest for them, and subject matter should not be isolated from the student's life experience. He believed that students need to be active learners, not passive ones (Dewey, 1916). The balance between the traditional and progressive education methods was one that allowed students choice in their learning with teachers guiding them through the process.

Dewey (1938) believed that experience comes through social interactions, and learning needs to be social. The teacher is a part of the education organization, but their role is not one of a boss or a dictator (Dewey, 1938). The teacher is there to guide students to appropriate learning activities. Dewey (1938) said this about teachers:

> I do not know what the greater maturity of the teacher and the teacher's greater knowledge of the world, of subject-matters and of individuals, is for unless the teacher can arrange conditions that are conducive to community activity and to organizations which exercises control over individual impulses by the mere fact that all are engaged in communal projects. (p. 57)

The teacher must be aware of students' needs and capabilities to arrange a learning environment that simultaneously meets the student's needs and provides the proper subject matter for this content. This learning environment of experiences truly moves from teacher-centered to learner-centered. The teacher moves from the boss or dictator to the director of group activities. The flipped classroom approach aims to transform teachers into a director of active learning activities.

Vygotsky's Zone of Proximal Development

Vygotsky (1978) believed that learning is inherently a social construct, and he highlighted the importance of language and dialogue in the instruction of children. Vygotsky

(1978) believed students do not gain knowledge through the lecture of new materials in the classroom and imitation of the teacher. The students needed to be able to collaborate with peers and seek guidance from adults. A student can imitate many actions on the board in a lecture, but they still need to internalize the learning and understand the concepts. Vygotsky (1978) believed that "human learning presupposed a specific social nature and process by which children grow into the intellectual life of those around them" (p. 88). Language mediates students' thoughts through internal speech and reflection.

Vygotsky (1978) believed that maximum learning occurs in a zone of proximal development essential to understanding. The zone of proximal development (ZPD) is defined as "the distance between the actual development level as determined by independent problem solving and the level of potential development as determined through problem-solving under adult guidance or in collaboration with more capable peers" (p. 86). To Vygotsky (1978), learning happens when students interact with people in their environment and cooperate with their peers to form internal development processes. After this cooperation and internalization, the processes become a part of the student's foundations of the topics. Learning is genuinely achieved when students can demonstrate their knowledge without the need for the help of others, demonstrations, or leading questions to guide them.

Teachers can scaffold learning in cooperative learning groups to help students move through the zone of proximal development. The origins of today's scaffolding techniques are credited to Vygotsky. Although Bruner (1985) asserted there is no overt mention of scaffolding in Vygotsky's works, he affirmed that ZPD was sometimes given credit for the hidden agenda of scaffolding. Shvarts and Bakker (2019) presented some evidence that Vygotsky's theory of ZPD is the approximate start of scaffolding. Pardjono (2016) credits Vygotsky with the scaffolding

concept, a method for teachers to create and differentiate content for learners. Through scaffolding, the student has assistance with the help of an adult or peer to internalize the ideas they are learning and help them to become independent learners (Shvarts & Bakker, 2019).

Flipped learning is a teaching method that provides class instructional time to scaffold student activities by working in peer groups to move through a zone of proximal development and provide an engaging learning environment. Dewey's and Vygotsky's learning theories and beliefs about student learning are compatible with the flipped classroom teaching model methods.

Definition and Dimensions of Engagement

Student engagement is often regarded as a multidimensional construct. Many researchers believe engagement is constructed of behavioral, emotional, and cognitive engagement (Fredricks et al., 2004). This research will include social engagement as a fourth dimension of engagement. The definition of engagement that informs this research incorporates all four dimensions of engagement, which are behavioral, emotional, cognitive, and social and is from Roman et al. (2022):

> The energy and effort that students employ within their learning community, observable via any number of behavioral, cognitive, affective, or *social* indicators across a continuum. It is shaped by a range of structural and internal influences, including the complex interplay of relationships, learning activities, and the learning environment. (p. S67)

This definition will help frame student engagement throughout this study and the various engagement frameworks for math and technology.

Behavioral Engagement

Behavioral engagement relates to students' positive conduct and proactive participation in academic activities (Wang et al., 2019), and is crucial for students to have a positive learning experience and prevent dropout (Fredricks et al., 2004). Students can exhibit behavioral engagement during class by participating in classroom activities, contributing to classroom discussions, and contributing to collaborative learning groups (Lo & Hew, 2021). Behavioral engagement is comprised of students' actions in the classroom that contribute to their participation and completion of work.

Affective Engagement

The second construct of engagement is affective or emotional engagement, also known as emotional engagement (Fredricks et al., 2004). Affective engagement deals with students' emotions and reactions to the interactions in the classroom and school, including willingness to work (Fredricks et al., 2004). Emotional engagement is more significant in a flipped classroom when students are interested in the content, involved with their peers, enjoy the class and learning new things, and have fun (Jamaludin & Osman, 2014). The flipped classroom has an opportunity to have greater social engagement due to the active, collaborative learning methods used.

Cognitive Engagement

Another construct of engagement is cognitive engagement. Cognitively engaged students were invested in their learning and demonstrated an enthusiasm to exert extra effort to understand and master complex skills and ideas (Fredricks et al., 2004). Lo and Hew (2020) found that the flipped classroom improves students' cognitive engagement by helping them understand math better, prefer challenging material, and increase knowledge outside the class.

Cognitive engagement is an internal drive in the students to push themselves to learn complex concepts and grow their desire to learn content outside of what is taught in class.

Social Engagement

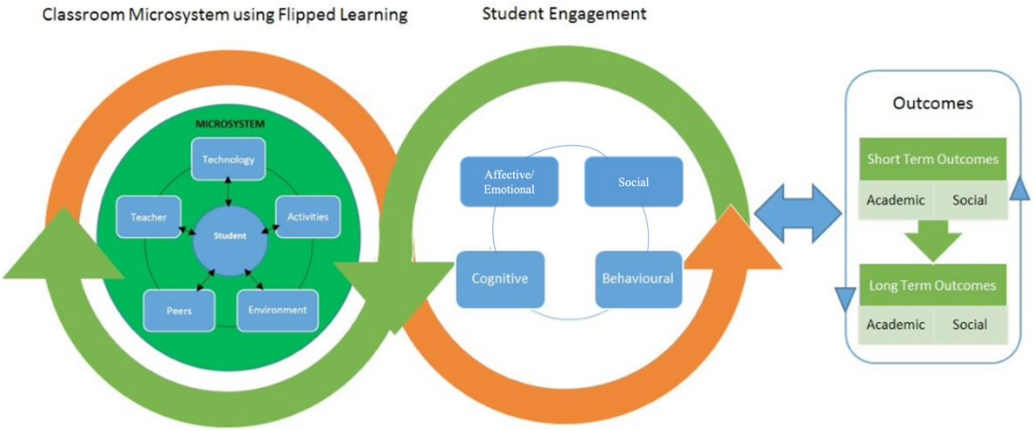
Recently, researchers added social engagement to the dimensions of engagement. The original dimensions of engagement studied traditional teaching methods and individual learners. There is a need to include a social aspect to classroom engagement by utilizing teaching methods that rely on social interaction (Fredricks et al., 2016; Linnenbrink-Garcia et al., 2011). Wang et al. (2016) stated, "Social engagement includes the interactions with peers and adults, as well as the willingness to invest in the formation and maintenance of relationships while learning" (p. 17). Social engagement in a flipped learning setting would include interactions with peers in collaborative learning groups and the instructor.

Flipped Learning Student Engagement Framework

Engagement does not occur without internal and external influences, and they are vital to understanding student engagement. In fact, research on student engagement offers a bioecological framework of engagement (Bond & Bedenlier, 2019). The bioecological model consists of a macrosystem, exosystem, mesosystem, and microsystem. The bioecological model includes many factors that are beyond the teacher's control in the classroom, so the framework for this study will focus on the flipped learning student engagement framework (see Figure 2) which is the microsystem that influences student engagement. In this microsystem, the interaction with the influences, student engagement, and long-term and short-term outcomes all affect one another (Bond, 2020). The flipped learning engagement framework keeps the student at the center of the microsystem, surrounded by influences that affect student engagement and the academic and social long and short-term outcomes.

Figure 2

Flipped Learning Student Engagement Framework



Note. Bond's (2020) framework is adapted to include social engagement with permission from Bond (M. Bond, personal communication, February 23, 2023).

The influences that affect student engagement within this microsystem and the student-teacher relationship, the learner-content relationship, the peer-peer relationship, the student-technology relationship, and the environment of learning. The student-teacher relationship is crucial to student engagement (Bond & Bedenlier, 2019; Hodgson et al., 2017). Teachers that are confident, approachable, and have knowledge of the content they teach and technology (Aycicek & Yelken, 2021) better foster student engagement (Bond & Bedenlier, 2019). Content that is authentic and presents a challenge to students (Attard, 2014; Bond & Bedenlier, 2019) while using collaborative active techniques (Bond & Bedenlier, 2019) is more engaging. Effective peer relationships within collaborative groups increase students' engagement, whether they are using technology (Bond & Bedenlier, 2019). Student technology knowledge and choice can lead to

greater student engagement (Attard, 2014; Bond & Bedenlier, 2019). All these influences can lead to student engagement or disengagement within a classroom.

Framework for Engagement with Mathematics (FEM)

This research focuses on not only engagement with technology in a flipped classroom setting but also engagement with mathematics. This FEM in Figure 3 discusses student engagement within a framework designed explicitly for mathematics classes from a three-year longitudinal study of middle school mathematics students (Attard & Holmes, 2020a). Attard (2014) initially created this framework to help teachers to design engaging math lessons, but it has also been used to assist researchers in analyzing qualitative data from math classes to determine how technology has affected student engagement. This framework will be used in this study to analyze the student engagement factors with mathematics within the AP Statistics flipped classroom.

Attard and Holmes (2020b) drew upon the multidimensional engagement construct proposed by Fredricks et al. (2004), which includes emotional, cognitive, and behavioral elements. However, emotional engagement was changed to affective engagement and behavioral engagement was changed to operative engagement, as noted in research by Munns (2007). He felt that these changes promoted a clearer educational focus for teachers when they discussed the dimensions of engagement (Munns, 2007). Attard and Holmes (2020b) defined the construct of engagement as:

> (Mathematical) engagement can be seen when students are procedurally engaged with the classroom, actively participating in tasks, and "doing" the mathematics with the view that learning mathematics is worthwhile, valuable, and useful within and beyond the classroom. (p. 40)

For Attard (2012), behaviorally (operatively) engaged students actively participated in group discussions and activities and completed tasks assigned to them. Emotionally (affectively) engaged students valued their learning and believed it would be helpful outside the classroom. Cognitively engaged students understood and had expertise in mathematical concepts and applications. The constructs of engagement are parallel with the definition and multi-dimensional aspects of engagement accepted by Fredricks et al. (2004) but focused on the math context.

Attard and Holmes' FEM (2020b) stated that pedagogical relationships and repertoires are separate but interconnected elements that influence student engagement. These aspects of student engagement in the math classroom are developed from student feedback on their beliefs of a good mathematics lesson (Attard, 2014). For students to experience engagement, teachers must form positive, interpersonal relationships with their students (Attard & Holmes, 2020b). Student engagement increases when teachers have strong content knowledge (Bond & Bedenlier, 2019), display enthusiasm for math concepts, understand students' backgrounds and pre-existing knowledge, and provide timely feedback for student improvement (Attard & Holmes, 2020b). Opportunities for challenging yet accessible tasks that cater to diverse learners and provide students with choices are engaging for students (Attard & Holmes, 2020b; Bond & Bedenlier, 2019). Students are also engaged when the content is relevant outside of classroom learning and authentic, while giving them choice, and technology is embedded to enhance the understanding of math (Attard, 2014). This framework includes middle school (5-8) students' perspectives on what type of activities drive engagement in a math classroom.

Figure 3

The Framework for Engagement with Mathematics (Attard, 2014)

Aspect	Code	Element
Pedagogical Relationships	In an engaging mathematics classroom, positive pedagogical relationships exist where these elements occur:	
	TA	Teacher Awareness: the teacher is aware of each student's mathematical abilities and learning needs
	PK	Pre-existing Knowledge: students' backgrounds and pre-existing knowledge are acknowledged and contribute to the learning of others
	CI	Continuous Interaction: interaction amongst students and between teacher and students is continuous
	CF	Constructive Feedback: feedback to students is constructive, purposeful and timely
	PCK	Pedagogical Content Knowledge: the teacher models enthusiasm and an enjoyment of mathematics and has a strong Pedagogical Content Knowledge
Pedagogical Repertoires	Pedagogical repertoires include the following aspects:	
	CT	Challenging Tasks: tasks are positive, provide opportunity for all students to achieve a level of success and are challenging for all
	RT	Relevant Tasks: the relevance of the mathematics curriculum is explicitly linked to students' lives outside the classroom and empowers students with the capacity to transform and reform their lives
	PC	Provision of Choice: students are provided an element of choice
	VT	Variety of Tasks: mathematics lessons regularly include a variety of tasks that cater to the diverse needs of learners
	SC	Substantive Conversation: there is substantive conversation about mathematical concepts and their applications to life
	ST	Student-centred Technology: Technology is embedded and used to enhance mathematical understanding through a student-centred approach to learning
Students are engaged with mathematics when:		
• Mathematics is a subject they enjoy learning • They value mathematics learning and see its relevance in their current and future lives, and • They see connections between the mathematics learned at school and the mathematics used beyond the classroom		

Note. Used with permission from Attard (2022)

Definition of Terms

The following section contains a list of terms frequently used in this study. Previous research supports the definition of the terms provided.

Active Learning – Active learning is the opposite of passive learning where students sit and listen to the teacher. Students enthusiastically participate in activities or discussions to promote learning through collaboration and higher-order thinking (Freeman et al., 2014).

Student Engagement – The energy and effort students employ within their learning community, observable via any number of behavioral, cognitive, affective, or *social* indicators across a continuum. Various structural and internal influences, including the complex interplay of relationships, learning activities, and the learning environment that shape it (Bond & Bedenlier, 2019, p. 3; Roman et al., 2022, p. S67).

Affective Engagement – Students' emotions and positive and negative reactions to the interactions in the classroom and school, including willingness to work (Fredricks et al., 2004).

Behavioral Engagement – The level of participation, involvement in tasks, and (Fredricks, 2014).

Cognitive Engagement – Students' inclination to invest in learning through thoughtfulness and exertion of mental effort (Fredricks, 2014).

Social Engagement – Students' relationships with peers and adults in the classroom, and their investment in forming and maintaining rapports during learning (Wang et al., 2016).

Student Disengagement – A lack of engagement, effort, or persistence. Students can become apathetic towards learning and give up (Skinner et al., 2009).

Affective Disengagement – "Enervated emotion (tired, sad, bored), alienated emotion (frustration anger), and pressured participation (anxiety)" (Skinner et al., 2009, p. 496).

Behavioral Disengagement – "Core behaviors of disengagement- namely, passivity, lack of initiation, lack of effort, and giving up…they include mental withdrawal, and ritualistic participation, such as lack of attention and going through the motions" (Skinner et al., 2009, p. 496).

Cognitive Disengagement – "Lack of persistence and cognitive effort directed at completing the task rather than understanding the material" (Wang et al., 2019, p. 603).

Social Disengagement – "Not feeling noticed by people at school; not feeling that interacting with peers is an important part of school; and not caring about people at school" (Wang et al., 2019, p. 597).

Collaborative Learning – "Opportunities for students to work in small groups on an open-ended problem with no clear answer; the teacher plays a more facilitative role" (Fredricks, 2014, p. 190).

Flipped Classroom – an instructional model that moves direct instruction away from the classroom, typically by having students watch instructional videos before class; and use the repurposed face-to-face class time to "practice learning concepts, engaging activities, and higher-order thinking" (Bergmann & Sams, 2015, p. 6).

Flipped Learning – "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" (Flipped Learning Network, 2014a).

Self-efficacy – "Individuals' beliefs about their ability to succeed in a situation" (Fredricks, 2014, p. 58).

Self-regulation – “Process by which learners attempt to monitor and control their own learning” (Fredricks, 2014, p. 119).

Summary

This research will be guided by the learning theories of Dewey (1916, 1938) and Vygotsky (1978). Dewey (1916, 1938) believed that students learned socially and should have choices in their education. Vygotsky (1978) believed that students socially constructed their learning with more knowledgeable others that help them move from their prior knowledge through a zone of proximal development to understand foreign concepts with a goal to work independently. The flipped classroom provides students with direct instruction through videos watched outside the classroom, which adds to their prior knowledge before class. Students construct knowledge collaboratively during class to move from a low level of understanding to higher-order thinking skills to apply knowledge to real-world applications, during which students must be engaged in learning. Students’ perspectives on engagement tools and strategies are not often studied. Therefore, this research aims to understand the varied lived engagement experiences of students in a flipped AP Statistics class; furthermore, this phenomenographic study desires to understand engagement through students’ perspectives to provide tools and strategies for math teachers to drive engagement in a flipped math classroom. Bond and Bedenlier’s (2019) framework for engagement in a flipped classroom and Attard and Holmes’ (2020b) framework for math engagement undergird the understanding of student engagement and offer descriptors during data analysis.

Chapter Two: Literature Review

This literature review aims to analyze and synthesize previously conducted research on engagement related to flipped learning, engagement in math classrooms, and engagement with technology to show this study's current research and placement within the recent literature. Studies being analyzed have been limited to the K–12 setting except for research engagement in statistics flipped classrooms. Statistics is often taught at the collegiate level rather than the secondary level. The chapter starts with a discussion of the literature research strategy. It continues by looking at engagement and disengagement in the flipped classroom, math classroom, statistics classroom, and with technology.

Literature Search Strategy

Google Scholar and Kennesaw Library's search engines were used to search for articles to inform the literature review. The research databases included ERIC, JSTOR, Taylor & Francis Online, ProQuest, Springer, and EBSCO. Any article not available through these services was requested through Kennesaw Library's inter-library loan; most commonly, these were articles from Elsevier. The research initially focused solely on the flipped classroom and flipped learning. The original search term used was *flipped classroom,* and I quickly changed the search terms to include *flipped learning* and *inverted classroom.*

In the original search, the research on the flipped classroom focused predominantly on a few topics. The topic found frequently when searching for the flipped classroom related to *student achievement.* Other studies included *student perceptions*, *flipped satisfaction*, and *student engagement.* These searches showed few studies about engagement in flipped learning were conducted at a secondary level, and even fewer were done in a statistics classroom. Birgili et al. (2021) found that in flipped classroom research from 2012 to 2018, only 12% of the 321 studies

were done at the secondary high school level. Many studies focused on post-secondary or undergraduate classes. Given this, the search terms expanded to include *secondary mathematics*, *engagement*, and *flipped classroom/learning/inverted classroom.*

After researching prevalent topics on flipped learning, student engagement was determined to be a good focus for this study. Student engagement has often been studied as a pressing issue in education. It is commonly known as a multidimensional construct with behavioral, affective, and cognitive dimensions (Fredricks et al., 2004), and only recently has a fourth dimension been added to include social engagement (Fredricks et al., 2016; Linnenbrink-Garcia et al., 2011; Wang et al., 2016). Social engagement is an essential aspect of engagement to study in flipped learning as the students interact with each other more in this format through active, collaborative learning. In most recent research, social engagement has been considered a critical fourth dimension of engagement (Bond et al., 2020; Linnenbrink-Garcia et al., 2011; Wang et al., 2016). Engagement is slowly becoming focused on four dimensions, but only a few studies address all four dimensions.

Few studies discuss the dimensions of engagement in the flipped secondary mathematics classroom, and fewer have studied social engagement included as a dimension of engagement. Bond and Bergdahl (2022) stated that more studies need to be conducted that include social engagement as a part of the engagement construct. With the multidimensional aspect of engagement in mind, the search was finally narrowed to studies that mentioned the construct of engagement in their study to understand the theoretical understanding of engagement presented.

Traditional Classrooms and Direct Instruction

In a traditional math classroom, teachers lecture in class and students complete homework independently. Teachers are lecturing on procedures and algorithms, followed by

students repeatedly practicing what they learned to build fluency with mathematical concepts (Hattie et al., 2017). When this format is used, students often come to class with questions about the previous night's homework. Class may start with a warm-up activity, and then often, several minutes are spent on homework questions students struggled with the night before (Bergmann & Sams, 2012). After homework questions are answered, the teacher will lecture on the new material and possibly, if there is time, have an activity for the students to extend their learning. A traditional classroom is very teacher-focused with very little time for activities.

Traditional teaching methods differ from direct instruction. Direct instruction is done with intention and scaffolds learning for students (Hattie et al., 2017). Direct instruction has visible, purposeful learning goals, demonstration of concepts, checks for understanding, and closure (Hattie et al., 2017). The current standards for mathematics call for a focus on rigor (Hattie et al., 2017). Mathematical rigor "calls for a balance among conceptual understanding, procedural skills and fluency, and application" (Hattie et al., 2017, p. 3; NCTM, 2014). There are appropriate times for direct instruction in math learning, but the National Council of Teachers of Mathematics (NCTM) (2014) called for high-leverage teaching procedures to impact student learning. Among these high-leverage practices are facilitating meaningful math discourse, building procedural fluency from conceptual understanding, and supporting productive struggle in learning mathematics.

The flipped classroom uses the high-leverage practices suggested by the NCTM (2014) and provides for mathematical rigor. Class time in a flipped classroom looks different than a traditional classroom to make more time for active, student-centered learning (Bergmann & Sams, 2012). Flipped learning is a teaching method that allows teachers to move traditional

methods of teaching that require less rigorous instructional strategies outside of the classroom and makes more time for rigorous mathematical instruction inside the classroom.

Flipped Learning Definition and Fours Pillars

The Flipped Learning Network (2014a) defined flipped learning and Pillars of the F-L-I-P to help combat misconceptions and myths clouding people's understanding of flipped learning. The Flipped Learning Network (2014a) defines flipped learning as:

> 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.

Flipped classrooms that utilize flipped learning operate in two spaces and have two teaching methods.

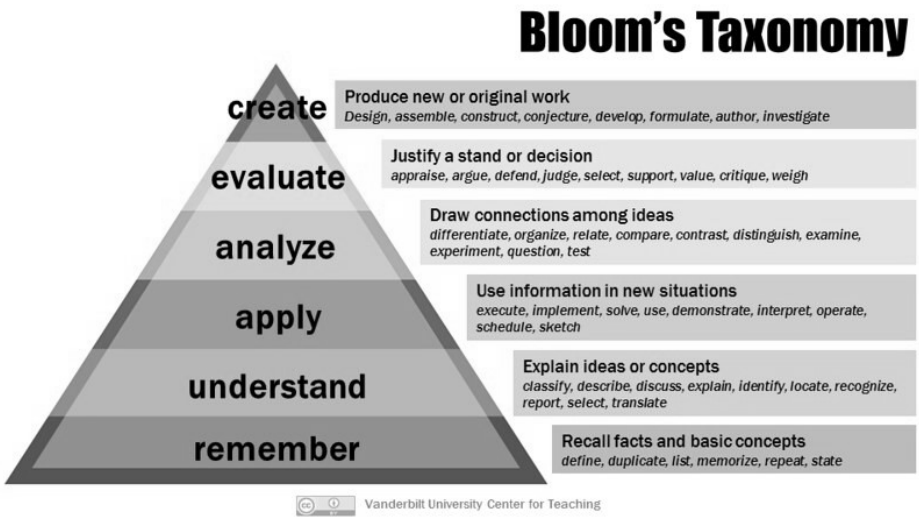
The first space of the flipped classroom is the individual learning space. In this space, students watch videos, read content, or listen to content created or chosen by their teacher for direct instruction at home. Pre-class learning is taught from a behaviorist perspective, teaching through repetition and reinforcement. The pre-class learning content should be introductory (Lo et al., 2017), where students are asked to understand and remember basic ideas (Armstrong, 2010). The individual learning space provides lower order thinking on Bloom's Taxonomy (see Figure 4), such as recalling facts. Pre-class learning in the flipped classroom is largely focused on behaviorist learning structures of repetition and reinforcement so students can recall facts or have a basic understanding of the learning that will be done in the group learning space.

The second learning space is the group learning space, taught with constructivist methods. During class, in the group work environment, learning is active (Flipped Learning

Network, 2014a). Students use introductory understanding from the pre-class content in new settings to apply their knowledge while they analyze and make connections among the ideas (Lo & Hew, 2020). Students actively participate in evaluating the content through discourse on the problems they are working on to form a deeper understanding of the learning topic (Cevikbas & Kaiser, 2021). While working through the higher levels of Bloom's taxonomy, they are working with peers and the teacher to move through the zone of proximal development to reach higher-order thinking skills and connections to learning.

Figure 4

Bloom's Taxonomy



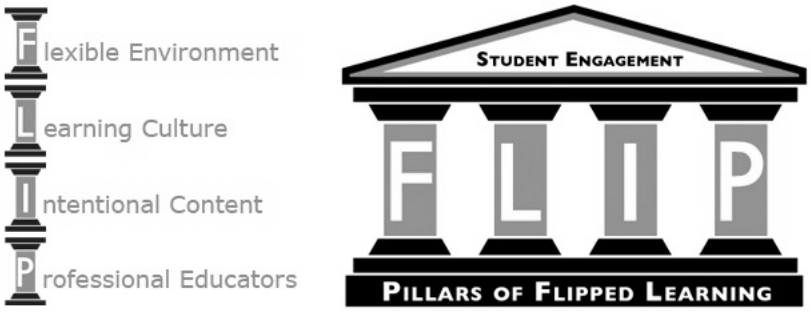
Note. From Bloom's Taxonomy [Photograph], by Vanderbilt University Center for Teaching, levels of Bloom's 2016, Flickr https://www.flickr.com/photos/vandycft/29428436431. CC BY 2.0

Four Pillars of Flipped Learning

The Flipped Learning Network (2014b) offers four pillars to implement flipped learning successfully and support student engagement (see Figure 5). The first pillar is a flexible environment. Teachers are facilitators of learning and flexible in methods for students to demonstrate learning mastery. Flexibility also includes the willingness of a teacher to rearrange the classroom to support group or individual learning.

Figure 5

Pillars of Flipped Learning (Flipped Learning Network, 2014b)



Note: Used with permission from M. Moore, chair of Flipped Learning Network (M. Moore, Personal conversation, April 11, 2023)

The second pillar is learning culture. The learning environment in a flipped classroom is student-centered with scaffolded active learning experiences (Flipped Learning Network, 2014b). The scaffolding ensures that diverse learners are successful. The classroom activities focus on higher-order learning activities that build on pre-class learning. In this environment, the

learning theories of Vygotsky (1978) discuss scaffolding and placing students within their zone of proximal development.

The third pillar is intentional content. Teachers prioritize the content learned in individual and group learning environments (Flipped Learning Network, 2014b). The flipped classroom teacher determines the pre-class content and what students can learn without the teacher's assistance. The teacher also determines the classroom content and provides student-centered active learning with teacher guidance to move students to a more profound knowledge of the content and higher levels of Bloom's taxonomy.

The last pillar is the professional educator. The teacher observes students, provides feedback, and assesses student work in the group space or classroom learning (Flipped Learning Network, 2014b). The teacher collects formative data to inform their teaching. The teacher forms relationships with their students. Professional educators also collaborate with their peers to continually reflect on and improve their practices with students.

The flipped classroom provides increased time for students to experience collaborative, active learning environments, which can move them from lower-order thinking to the higher-order thinking of Bloom's Taxonomy (Vanderbilt University Center for Teaching, 2016). Research has been written about both benefits and drawbacks of flipped classrooms and flipped learning, and the following sections present the prevalent research on the flipped classroom in K-12 education and college-level statistics in flipped classrooms.

Research on Engagement in the Flipped Classroom

The research to support this study was limited to 2016 and newer because technology has significantly advanced since the flipped classroom's beginnings. All the studies researched define the flipped classroom as a method of teaching that allows for active learning within the

classroom and has videos for the pre-class content. The following section shows the advantages and disadvantages of the flipped classroom in literature.

Advantages of the Flipped Classroom

Research shows that students generally have positive reactions to the flipped classroom. Some research shows that students prefer the flipped classroom to the traditional method of teaching (Birgili et al., 2021; Florence & Kolski, 2021; Pardimin et al., 2022). Students report increased motivation (Cevikbas & Kaiser, 2021; Graziano & Hall, 2017; Tapia et al., 2021; Unal & Unal, 2017) and enthusiasm (Etemadtfar et al., 2020; Wilson, 2021) in the flipped classroom. Students convey increased confidence and self-efficacy (Avery et al., 2018; Conner, 2021; Yang et al., 2021). These positive outcomes relate primarily to two components of the flipped classroom: self-paced videos and classroom collaboration.

Students appreciate the ability to learn outside the classroom on a schedule they create. Often the feelings of positivity are because students enjoy the self-paced learning that the videos provide (Bhagat et al., 2016; Cevikbas & Argum, 2017; Conner, 2021; Graziano & Hall, 2017; Tapia et al., 2021; Yang et al., 2021). The ability to stop, pause and rewind the video allows the students to determine their own pace when learning content (Hew et al., 2021; Unal & Unal, 2017; Urbano et al., 2020). Students also like the ability to rewatch videos to better understand the material for pre-class learning or to review the content for assessments (Unal & Unal, 2017). The self-paced nature and accessibility of videos in the flipped classroom led to students' satisfaction.

In addition to self-paced learning, collaboration is critical to the flipped learning environment and research has shown that student-student and student-teacher relationships improved in a flipped classroom setting. Students value collaborative communication and hands-

on classroom learning (Avery et al., 2018; Cevikbas & Argum, 2017; Cevikbas & Kaiser, 2021; Conner, 2021; Florence & Kolski, 2021; Katsa et al., 2016; Kostaris et al., 2017; Pardimin et al., 2022; Urbano et al., 2020; Wilson, 2021). The collaborative nature of the flipped classroom increases students' abilities to cultivate strong peer-to-peer and student-to-teacher relationships (Avery et al., 2018; Aycicek & Yelken, 2021; Cevikbas & Kaiser, 2021; Kostaris et al., 2017; Muir, 2018; Tapia et al., 2021; Unal & Unal, 2017). Through collaborative learning, students share problem-solving techniques (Cevikbas & Argum, 2017) and gain an increased understanding of the concepts (Pardimin et al., 2022). Student-teacher relationships were crucial, and Muir (2018) found that students were motivated to learn and watch videos because they respected their teacher. The flipped classroom allows teachers to gain more knowledge about their students (Tapia et al., 2021) and form relationships with their students (Avery et al., 2018; Aycicek & Yelken, 2021; Cevikbas & Kaiser, 2021; Kostaris et al., 2017; Muir, 2018; Tapia et al., 2021; Unal & Unal, 2017). Many positive outcomes of the flipped classroom occur due to the collaborative nature of activities in the flipped classroom.

When students are collaboratively learning, it promotes higher cognitive skills and participation in active learning. Students think critically (Cevikbas & Kaiser, 2021; Zupanec et al., 2022), can solve higher-order thinking problems (Cevikbas & Kaiser, 2021; Yang et al., 2021; Zupanec et al., 2022), and have an increased conceptual understanding of the content (Tapia et al., 2021). Students connect with previous and pre-class learning (Cevikbas & Kaiser, 2021; Wilson, 2021) and can independently remember and apply their knowledge (Cevikbas & Kaiser, 2021). When working collaboratively, students experience increased understanding of concepts and how to apply their knowledge.

Engaged students with positive connections with their instructors tend to improve academically and have less disruptive classroom behaviors. Discipline issues and absenteeism decrease when implementing the flipped classroom (Cevikbas & Argum, 2017). Some studies reported that teachers said students in a flipped classroom have increased time on task (Cevikbas & Kaiser, 2021; Wilson, 2021). One reason that students may have increased time on task and less discipline issues was that teachers could provide timely feedback to their students (Cevikbas & Kaiser, 2021) and assist students struggling with the concepts.

Students who are engaged in the classroom have better academic outcomes. Many studies show that the flipped classroom leads to increased academic achievement over the traditional classroom (Bergmann & Sams, 2015; Bhagat et al., 2016; Birgili et al., 2021; Etemadtfar et al., 2020; Florence & Kolski, 2021; Guler et al., 2022; Hew et al., 2021; Lag & Saele, 2019; Pardimin et al., 2022; Sablan & Prudente, 2022; Spotts & Gutierrez de Blume, 2020; Zupanec et al., 2022). Some studies demonstrate that academic achievement happens because students see the learning goals twice, before class and during class, which can lead to confidence when completing classroom tasks (Etemadtfar et al., 2020; Hew et al., 2021; Kapur et al., 2022). Other studies believe that because of the maximized time for student collaboration in classroom activities (Kostaris et al., 2017), students see a positive effect on their cognitive learning (Birgili et al., 2021; Cheng et al., 2018; Florence & Kolski, 2021; Katsa et al., 2016). Students' understanding of mathematics deepens when active learning strategies are used (Torres-Martin et al., 2022). Academic achievement can improve through content repetition, peer collaboration, and active learning strategies in the flipped classroom.

Disadvantages of Flipped Learning

Research has outlined advantages of flipped learning, but some disadvantages have also been found. Some students still experience the digital divide and need home access to devices or the internet (Cevikbas & Argum, 2017; Satparam & Apps, 2021). These students do not have access to the internet or devices at home, which could be a significant deterrent to being able to participate in the flipped classroom.

While some students have difficulties accessing the internet, others are unwilling to adapt to the differences between flipped learning and traditional instruction. Some students are resistant (Lag & Saele, 2019; Satparam & Apps, 2021; Torres-Martin et al., 2022) or have difficulty adapting to the flipped classroom (Cevikbas & Argum, 2017; Cevikbas & Kaiser, 2021; Satparam & Apps, 2021). The students with the most resistance had been taught in a traditional classroom and needed to familiarize themselves with the flipped classroom (Cevikbas & Kaiser, 2021; Lo et al., 2017). Those that did not understand the learning structure preferred direct instruction methods (Cevikbas & Argum, 2017). Some students complained teachers were not present to answer questions while watching pre-class learning videos (Lo et al., 2017). The lack of experience with the learning method and guidance at home can lead to disengagement in pre-class learning.

Students can also experience disengagement in the flipped classroom due to their perceptions of an increased workload from watching videos and problems with time management. Video length can cause disengagement (Lo et al., 2017; Wilson, 2021) and boredom (Unal & Unal, 2017) for students, especially when videos are too long. Watching videos requires students to change their study habits (Guo et al., 2014; Satparam & Apps, 2021; Tapia et al., 2021), which is not always easy for students and can lead to resistance. Studies also

reveal that students perceived an increased workload (Lag & Saele, 2019), disdained homework and the flipped classroom (Unal & Unal, 2017), or have problems with time management (Florence & Kolski, 2021). Students may need more motivation or accountability (Satparam & Apps, 2021) to adjust their habits at home. When students experience frustration, boredom, disengagement, lack of time management skills, or do not have technology at home, the students can have difficulties watching videos.

The research about student engagement and disengagement in flipped learning shows many positive engagement factors like enthusiasm, motivation, self-regulation, higher cognitive thinking skills, and positive interactions with peers and teachers through collaborative activities. Studies also show some negative aspects like students being unwilling to change and adapt, unwilling to do homework, and generally unprepared for the classroom. These behaviors are indicators of all the dimensions of engagement. Positive affective engagement happens when students show enthusiasm (Wilson, 2021) and motivation (Cevikbas & Kaiser, 2021; Graziano & Hall, 2017; Tapia et al., 2021; Unal & Unal, 2017). Positive cognitive engagement is shown through self-regulation of their learning (Bhagat et al., 2016; Cevikbas & Argum, 2017; Conner, 2021; Graziano & Hall, 2017; Tapia et al., 2021; Yang et al., 2021) and learned higher cognitive skills through critical thinking during active learning (Cevikbas & Kaiser, 2021; Zupanec et al., 2022). Positive social engagement is found in collaboration and relationships built with both peers and teachers (Avery et al., 2018; Aycicek & Yelken, 2021; Cevikbas & Kaiser, 2021; Kostaris et al., 2017; Muir, 2018; Tapia et al., 2021; Unal & Unal, 2017). Most disadvantages occur through behavioral disengagement factors like an unwillingness to do outside work (Lag & Saele, 2019; Satparam & Apps, 2021; Torres-Martin et al., 2022). Students can also experience affective disengagement factors like an unwillingness to work outside the classroom or hating

homework (Unal & Unal, 2017). Research has found many factors of engagement and disengagement, which are useful for measuring engagement and disengagement factors found in research to measure student engagement and disengagement.

Measures of Student Engagement

The concept of engagement has been widely studied, but often it is difficult to quantify or define engagement. Studies are sometimes very vague when it comes to the concept of engagement that they are studying. Given similar data sets, different researchers may come up with different perceived outcomes of the data without a strong understanding of the indicators of engagement (Fredricks & McColskey, 2012). The lack of a unified operational definition for engagement causes difficulty in making comparisons of the outcomes of studies. The indicators of engagement and disengagement published by previous researchers will be used to examine and measure engagement in the student responses to the interview questions to create a basis for comparison for this research to previous and possible future research.

Table 1

Advantages and Disadvantages of the Flipped Classroom

Advantages of the flipped classroom	Disadvantages of the flipped classroom
• Self-efficacy	• Digital divide
• Increased confidence	• Resistance to new teaching strategy
• Increased motivation	• Difficulty adapting to flipped learning
• Enthusiasm	• Prefer direct instruction in class
• Self-paced and available videos	• Increased workload for students and teachers
• Improved teacher-student relationships	• Disdain for homework
• Improved student-student relationships	• Lack of motivation
• Shared problem-solving techniques	• Students need new study habits
• Increased conceptual understanding	• Video length is too long

• Increased time on task • Decreased absenteeism • Teacher knowledge of students • Timely feedback • Teacher one-on-one assistance • Increased academic achievement • Better for ELL and disabled students • Low performing students more successful • Increased time for active and collaborative learning in the classroom • Repetitive learning of lesson goals	• Student time management issues

Student Engagement Indicators. While systematically analyzing 243 articles on student engagement, Bond et al. (2020) found the top five student engagement indicators to be learning from peers, deep learning, self-regulation, positive self-perception, and critical thinking. Each dimension of engagement had its own set of indicators, demonstrating measurable variables in each dimension (Bond & Bedenlier, 2019). However, their research did not include the social dimension in engagement. The indicator lists from Roman et al. (2022) and Wilson (2021) research studies represent the engagement indicators found in research (see Table 2).

Student Disengagement Indicators. Studies of engagement have also found factors of disengagement. Most teachers describe disengagement as behaviors (Wang et al., 2019)- playing on phones, misbehaving, and other ways of looking disengaged. Disengagement is not always evident in outward behaviors, and students can be actively engaged in one dimension of engagement while simultaneously being disengaged in another (Groccia, 2018). Engagement is a complex construct. While studies show students are engaged in learning, there is also evidence of student disengagement. Engagement and disengagement are not opposite ideas; students can be simultaneously engaged in one dimension and disengaged in another.

The student disengagement indicators found by previous researchers are listed (see Table 3). The top five disengagement indicators in a synthesis of many engagement studies are opposition/rejection, pressure, other, unwilling/avoidance, and feeling overwhelmed (Bond et al., 2020). The disengagement indicators found by Roman et al. (2022) and Wilson (2021) have been combined into one list.

Table 2

Engagement Indicators by Dimension

Type of Engagement			
Behavioral	Affective	Cognitive	Social
• Identifying opportunities & challenges	• Positive learning attitude	• Integrating ideas	• Asking a teacher for help
• Staying on task/persistence	• Satisfaction	• Operational reasoning	• Teaching self & peers
• Study habits	• Curiosity	• Reflection	• Helping peers
• Attempting action/initiation	• Interest	• Care/thoughtfulness	• Supporting & encouraging peers
• Homework completion	• Feeling appreciated	• Preference for challenging tasks	• Building on each other's ideas
• Assuming responsibility	• Sense of belonging	• Doing extra to learn more	• Positive interactions with teachers
• Focus	• Sense of connectedness to school	• Use of sophisticated learning strategies	• Positive interactions with peers
• Attendance	• Confidence	• Concentration/focus	
• Positive conduct	• Desire to do well	• Self-regulation	
• Class participation	• Enthusiasm	• Justifying decisions	
• Asking for help	• Interest	• Critical thinking	
• Attention/focus	• Excitement	• Purposeful	
• Confidence	• Values learning	• Setting learning goals	
• Effort	• Positive attitude	• Deep learning	
	• Pride	• Self-efficacy	

Note. Engagement indicators are combined from Roman et al. (2022) and Wilson (2021)

Table 3

Disengagement Indicators by Dimension

Type of Disengagement			
Behavioral	Affective	Cognitive	Social
• Procrastination	• Boredom	• Aimless	• Working alone during group work
• Absences	• Anger	• Unwilling	• Withholding of personal ideas
• Inattentive	• Disinterest	• Apathetic	• Negative peer interactions
• Restlessness	• Self-blame	• Helpless	• Negative teacher interactions
• Distracted	• Frustration	• Objective	• Withdrawal during collaborative time
• Unprepared	• Worry/anxiety	• Hopeless	• Disinterest
• Task incompletion	• Overwhelmed	• Resigned	
• Give up	• Sadness	• Avoidance	
• Half-hearted	• Disappointment	• Pressured	
• Unfocused		• Opposition/rejection	
• Mentally withdrawn			
• Burnt out/exhausted			
• Poor conduct			

Note. Engagement indicators are combined from Roman et al. (2022) and Wilson (2021)

Engagement in Math and Statistics Classes

The engagement and disengagement indicators are related to all student engagement, even math engagement. Math engagement is a significant issue in schools today. Engagement declines as students advance through school (Attard, 2014; Hodgson et al., 2017). Often students disengage from math because it is a difficult subject or believe that they cannot succeed; only smart students can (Boaler, 2022; Hattie et al., 2017). Students' disengagement in math classes is caused by factors that students build as they advance through school.

Math teachers aim to help students move from disengaged to engaged. Engaged students find math stimulating and useful (Ingram, 2013). When students find math compelling and valuable, they participate and pay attention in class, complete homework, seek help when confused (Skilling et al., 2021), and persist in problem-solving (Irvine, 2020a); all these traits improve achievement (Deringol, 2020). Engaged students were not stopped by confusion or anxiety; they could self-regulate emotional responses and believed challenging problems were solvable in time (Ingram, 2013). Students show that they are engaged by participating in class by asking questions and answering them (Brown, 2008). Student engagement in math is evident in their participation, ability to self-regulate their emotions, and perseverance despite setbacks in their learning.

When students have a high level of engagement, they tend to have higher scores, achieve more (Deringol, 2020; Norton, 2017), and have increased self-confidence in an active classroom (Irvine, 2020a). Engaged students also value and enjoy mathematics and tend to pursue an understanding of the concepts when working on a problem rather than focusing on the grade they receive (Skilling et al., 2021). Students understand which students are engaged and judge each other in class based on their levels of engagement (Anderson, 2007). When working in groups,

engaged students looked to pair with other engaged students (Brown, 2008), and other students also tried to move toward engaged students because they felt they could improve their grades (Brown, 2008). Engaged students enjoy math, perform well, and participate in the classroom.

Students' engagement can also be affected by parental support (Brown, 2008) and the perceived parents' opinion of the value of math (Martin et al., 2015). Students' value of math is directly related to their parents' values; their parents can also affect their feelings about school and the importance of technology (Martin et al., 2015). The engagement impacted by parental support is often outside the teacher's control. But not all students that look engaged in class are engaged necessarily.

Students Faking Engagement

Engagement is not always outwardly evident. Fuller et al. (2018) did a study on engagement and found that the observations of students were not necessarily reliable in determining student engagement. In this study, observers marked students pretending to be learning as engaged 90% of the time, while students testified that they pretended to be engaged 23% of the time. Students typically pretended to be engaged to show respect for a teacher or a desire to stay out of trouble. Students faking engagement are sometimes confused for students that are on task.

Schlechty (2011) states that on-task students are often confused with engaged students. He posits that for students to be engaged, they must be attentive, committed, persistent, and find meaning and value in the work that they are doing. On-task students are only attentive. The essential difference between engaged and disengaged students is how they relate to the given task. Schlechty (2011) defines five levels of student responses to a learning task: engagement, strategic compliance, ritual compliance, retreatism, and rebellion. Schlechty (2011) defines

strategic compliance as a student working because of an extrinsic award. These students only extend their time and energy to get rewards like a grade or approval from a parent. A ritually compliant student is easily distracted; you might find them texting in class (Schlechty, 2011). They are easily discouraged and avoid the task, often only completing the task when being monitored. A student engaged in retreatism does not work but does not distract their classmates (Schlechty, 2011). The student does not work independently, and when forced to work through supervision, they engage in ritual behavior or rebellion by refusing to work. They will cheat or overtly work on something else and may sabotage students around them. These students can disturb the classroom and sometimes form alliances with others in the same frame of mind to worsen the class (Schlechty, 2011). The student rebelling is often engaged in something but disengaged from the in-class learning.

Attributes of Disengaged Math Students

Research has revealed attributes of math disengagement. Students who do not like math find it difficult and incomprehensible (Ingram, 2013). These students may have been behaviorally engaged in the math classroom but did not seek to understand the problem. They seek to memorize the concept or procedure to get an answer (Ingram, 2013). Research shows these students can feel inferior and stupid (Ingram, 2013) and are less apt to seek assistance (Skilling et al., 2021). Females are more likely to discuss disengagement and fear of looking dumb (Fredricks et al., 2018) than males. Students that feel inferior and stupid are often not skilled at self-regulation, which leads to being overwhelmed, anxious, and uncertain about their math abilities (Skilling et al., 2021). When students start to feel all these negative emotions, it leads to self-handicapping behaviors, avoidance, and ultimately failure (Skilling et al., 2021). Disengagement and negative emotions affect students' ability to remain engaged in math lessons.

Students who experience boredom and anxiety in math class may be unwilling to participate in activities and start disruptive behaviors in the math class to disturb others (Ozkal, 2019) or be off task when the teacher stops talking (Brown, 2008). Norton (2017) posits that boredom is a multidimensional emotion. The dimensions Norton (2017) attributed to boredom are lack of fun, indifference, lack of excitement, no instant gratification, instruction that does not align with goals and values, and a lack of capacity to understand the topic.

Bored, anxious students may lack self-efficacy and are unsure how to express or self-regulate their emotions. Students who lack self-efficacy and self-regulatory skills have difficulty remaining engaged when frustrated (Brown, 2008). They quit, do not do assignments, or stop paying attention in class (Brown, 2008). The most significant difference between successful and low-performing students was a belief that they were not capable math students (Skilling et al., 2021). Skilling et al. (2021) found that these students had low confidence, confusion with topics, negative emotions about math, or were not concerned about misunderstanding math. These students may be helped by one-on-one teacher tutoring, but it is temporary. The student stops working when the teacher leaves because these students do not have the cognitive skills to work individually (Norton, 2017). When students stop paying attention in class or doubt their ability to be successful in math, it causes difficulty as they progress in school.

Math classes are ordered; students typically need to understand concepts from the previous math class to succeed in their current class. When students become disengaged and no longer focus on instruction, it causes gaps in students learning (Attard, 2021). The missing knowledge can lead to further disengagement. These students often do not have a foundational understanding of their study topic. This pattern of disengagement and gaps in math concepts damages students' self-efficacy and causes achievement to decline (Attard & Holmes, 2020b;

Maamin et al., 2022; Norton, 2017). Students' belief in their math abilities is not the only disengagement factor for math students.

Teachers can contribute to student disengagement. Students often report that they are disengaged in traditional classroom settings. The traditional approach can make students anxious as the teacher may focus too much on "drill and kill" skills and memorization (Attard, 2021). Students may be passive receivers instead of constructors of knowledge in the traditional setting (Fredricks et al., 2018). Teacher practices that were found to have sustained effects on cognitive and affective engagement are "strong relational pedagogy, highly consistent and structured routines, regular praise, and overt recognition of positive behaviour, consistent communication with parents, and movements of students with challenging behaviours away from triggering events" (Thomas & Nair, 2022, p. 674). Teachers can put some practices into place in the classroom to improve student engagement.

Strategies to Promote Math and Statistics Engagement

Research shows suggested strategies to promote student engagement. Active (Irvine, 2020a), collaborative and purposeful learning (Anderson, 2007; Shah et al., 2019) engage students in math. Active learning is more engaging than teacher-led lessons (Irvine, 2020a). Students who participate in fun collaborative learning activities feel more involved because they have fun (Anderson, 2007; Brown, 2008; Fredricks et al., 2018; Irvine, 2020a). Group work allows students to contribute different strengths to the group work (Irvine, 2020a).

Collaborative learning increases student engagement, but the tasks students are given during that time are also important. Student engagement increases when energy and activity levels in the classroom increase (Deringol, 2020). Hands-on activities with manipulatives created greater engagement (Fredricks et al., 2018; Fung et al., 2018; Irvine, 2020a). Authentic, real-

world tasks are more engaging for students (Brown, 2008; Irvine, 2020a, 2020b). Activities with whiteboards with teachers giving immediate feedback are engaging (Irvine, 2020a). When teachers monitor engagement, student understanding and scaffold assignments, students are more engaged (Brown, 2008; Fredricks et al., 2018). Students are also more engaged when they set goals (Irvine, 2020a). Structure and a variety of tasks can lead to increased engagement.

In addition to allowing students to collaborate and participate in various activities, it may be helpful for teachers to make students aware of the dimensions of engagement because students usually relate engagement to what they are doing behaviorally (Brown, 2008). Students do not realize how much emotions and moods can impact their engagement, especially their cognitive engagement (Brown, 2008). When students are anxious, their engagement wanes (Deringol, 2020). Teachers have a great deal of impact on students' emotional engagement (Irvine, 2020a). Teachers can impact students negatively when they react poorly in classroom situations. The role of teachers in students' emotions at school and their self-image as students is important (Thomas & Nair, 2022). Attard (2021) states that developing positive teacher-student relationships and knowing students as individuals is vital to student engagement. Teachers can impact student engagement through their relationships with students and by helping students to be aware of the social-emotional impact on their learning.

Strategies to improve engagement in the math classroom include using collaborative learning, teaching students about social-emotional engagement factors, and using active learning. These factors are also important in improving engagement in statistics classes.

Methods to Improve Engagement in Statistics

Statistics is classified as a math course and taught in the math department of most high schools. The College Board (2020) describes AP Statistics as the "equivalent to a one-semester,

introductory, non-calculus-based college course in statistics" (p. 7). Statistics courses not only require students to do calculations, but they require them to think (DeVeaux & Vellman, 2008). Statistics often requires students to have sound judgment and knowledge about the real world when solving problems, and students are required to write findings in sentences, not just symbolic math (DeVeaux & Vellman, 2008). Students must understand the data and describe the results to the reader, which is not always easy. There are some ways to increase engagement in the statistics classroom and help students communicate their results.

Collaborative learning is very effective in statistics classes (Chance et al., 2007). In group work, students can divide the workload, communicate ideas and solutions with peers, and synthesize learning with others' perspectives (Brown, 2008; Fredricks et al., 2018; Irvine, 2020a, 2020b; Shah et al., 2019;). Open-ended, interesting tasks provide student autonomy, control, and choice, increasing student engagement (Brown, 2008; Fung et al., 2018; Irvine, 2020b). Statistics should foster active learning. Active learning activities are group problem-solving and discussion, lab exercises, demonstrations with class-generated data, written and oral presentations, and group or individual projects (Cobb, 1992). Teachers should teach statistics as a laboratory science course (Cobb, 1992; Lee & Harrison, 2021). Students should use manipulatives and computers and get their hands "dirty with data" (Cobb, 1992, p 11). These learning techniques will help students to develop statistical thinking and reasoning skills.

The last question on the free-response section of the AP Statistics exam is an investigative task that requires students to use their statistical thinking and reasoning skills. The investigative task, as described in the AP Statistics Course and Exam Description, "assesses multiple skill categories and content areas, focusing on the application of skills and content in new contexts or non-routine ways" (College Board, 2020, p. 238). By actively learning through

hands-on, collaborative tasks, students can develop the skills to approach and succeed in the AP Statistics investigative task. Some teachers use the flipped classroom model to teach AP Statistics to have time for active learning activities like collaborative learning and problem-based activities to increase student engagement.

Dimensions in Math Engagement

Active engagement requires all dimensions of engagement if the goal is the retention of learning (Attard, 2021; Brown, 2008). All three aspects are statistically significant in student achievement (Fung et al., 2018). Students who only exhibit behavioral engagement rarely remember learning goals (Brown, 2008). Students experience higher achievement when they are engaged in two dimensions of engagement simultaneously rather than in only one dimension (Fung et al., 2018). Ingram (2013) states that "students' engagement can be compared according to their perseverance, mathematical intimacy, and integrity, the way they utilize their feelings, their concentration, independence, cooperation, and reflection" (p. 408). Students with self-efficacy, expectations of success, and a desire to demonstrate their knowledge in mathematical situations are emotionally and cognitively engaged (Ingram, 2013). If students only had one dimension of engagement, Fung et al. (2018) feel that the cognitive dimension is the most important. Maamin et al. (2022) found that affective engagement was the most significant predictor of achievement in high school students. Certainly, engagement is vital for students in mathematics. Teachers are struggling with waning student engagement in high school, so finding teaching strategies that counter student disengagement is crucial.

Technology Engagement

Although students' math engagement can be enhanced through technology, many math teachers struggle with using engagement in the classroom. Technology is known to boost

engagement in the classroom (Attard & Holmes, 2020a, 2020b; Biber et al., 2022; Funcheon, 2020; Salim et al., 2018), and technology is also known to increase engagement in the math classroom (Attard, 2021; Irvine, 2020a, 2020b; Salim et al., 2018). Despite this knowledge, many math teachers struggle with technology use and prefer classical teaching methods (Attard & Holmes, 2020b; Biber et al., 2022). When they implement technology, it is typically augmentation of the material, where technology is a substitute for the routine tasks done in mathematics (Attard & Holmes, 2020b). It is important for math teachers to be confident with their use of technology and use this as a tool to improve student engagement in learning math (Attard & Holmes, 2020a). Sometimes finding the right tool that promotes engagement and technology is difficult for math teachers because they need to "bridge the gap between learning and liking, which are often at odds" (D'Mello, 2021, p. 82). It is easy to find an entertaining technology tool that would be fun for students to use (D'Mello, 2021), but it can have a negative outcome if it does not support the learning goals (Morris & Parker, 2014). It is also challenging to find applications that provide student-centered practice at a high school level (Attard & Holmes, 2020b). Despite the knowledge that technology can improve engagement, math teachers often stick with traditional teaching methods due to the difficulty of finding the right technology tool or a lack of confidence with technology.

One of the ways that students encounter technology in a math class is through a learning management system (LMS), an easy tool where teachers can provide the content needed for class. This tool lets students transparently understand teachers' intentions for the class (Attard & Holmes, 2020b). An LMS will enable students to access content when convenient (Urbano et al., 2020). It also helps teachers to track student progress (Attard & Holmes, 2020b) and respond to and give feedback to students (Attard & Holmes, 2020a). Math-focused technology embedded in

an LMS also increases engagement (Attard & Holmes, 2020a). The LMS is an easy tool for teachers to organize content that engages students and track students' progress with these tools.

While math teachers can easily embrace an LMS, they are often reluctant to use mobile technologies, like cell phones, in their classrooms. Mobile technology increases engagement (Attard & Holmes, 2020a); however, app-based technology can also present issues. Mobile device apps, like PhotoMath, offer the potential to assist students in learning mathematics, but students can become app dependent (Attard & Holmes, 2020b). Students who are not engaged with math occasionally use the apps strictly for the answers, not to understand the material. Math applications can also be gamified. Gamified math learning can increase engagement (Attard & Holmes, 2020b) while influencing all the dimensions of engagement (Schindler et al., 2017). When using mobile devices, students can get off task quickly with other phone apps or text messages. Cell phones are a source of instant gratification for students; they do not often use them for difficult or complex tasks. Asking students to use their devices to learn means they must delay that gratification (D'Mello, 2021), which is very difficult for teenagers.

Technology must be used properly as it can be great for engagement and easily scaffold student work, but it may lead to waning student engagement if used too often. The use of applications and devices can lead to attention, effort, interest, and completion of student work (Funcheon, 2020). Teachers can use technology wisely to easily scaffold assignments and differentiate for students (Chiu, 2021). If the same tool is used too often, the initial novelty of technology can wane and eventually cause boredom (D'Mello, 2021). When using technology in the classroom, teachers need to ensure that technology supports the learning goal instead of just being used to implement it.

Technology Engagement in Statistics

The use of technology can significantly improve student engagement in statistics classes as technological tools and applets can quickly perform complicated displays and calculations. Technology can increase engagement and performance in statistics classes (Salim et al., 2018), and can significantly improve students' statistical learning (Chance et al., 2007). When learning statistics, students can be focused on computations and instead focus on the interpretations of statistical concepts (Chance et al., 2007). Students can do calculations quickly and accurately without needing complex mathematical formulas with the help of technology (Chance et al., 2007; Salim et al., 2018). Technology also enables statistics students to create detailed displays of data quickly (Chance et al., 2007; Salim et al., 2018). Using computers and graphing calculators can allow students to learn statistics without knowing the complex math calculations that go with it (Salim et al., 2018). On the AP Statistics exam, students are rarely asked to create graphs. They are more apt to be given graphs and asked to interpret the data in those graphs.

Students can use calculators and computers to give quick answers to complex math equations accurately and use many applets that simulate chance processes. Computer applets simulate chance processes in statistics (Chance et al., 2007). Simulations allow students to understand statistical concepts or to collect data quickly for inference procedures.

Summary

Engagement is a multi-dimensional construct. This literature review was conducted to understand what research has been done about flipped learning, engagement, math engagement, and technology engagement. While there is much research about engagement, most is done at the university level, not the secondary level. In addition, there is not much qualitative research. Most

of the studies found were quasi-experimental or mixed-method research. Bond et al. (2020) found the same in their systematic engagement and educational technology research.

Few published studies on the flipped classroom have defined engagement, and even fewer have described their engagement frameworks (Bond & Bedenlier, 2019). Only studies clearly defining or describing the engagement construct are included in this literature review. Hodgson et al. (2017) only studied behavioral engagement in the flipped classroom. Three other studies clearly defined engagement as a multidimensional construct with the three dimensions of engagement – emotional, cognitive, and behavioral (i.e., Aycicek & Yelken, 2021; Cevikbas & Kaiser, 2021; Lo & Hew, 2020). Two of these studies studied the flipped math classroom in high school– Algebra and Pre-Calculus classes (Cevikbas & Kaiser, 2021; Lo & Hew, 2020). Only one study in a biology course used all four dimensions of engagement– affective, cognitive, behavioral, and social (Wilson, 2021).

This study will fill a need in engagement research to study the four dimensions of engagement within an AP Statistics secondary classroom. This study will also use qualitative research methods through the phenomenographical lens to understand students' variations of lived engagement in the course by analyzing student journals and student interviews. This approach will allow students to have a voice in talking about their engagement and for analysis of strategies used and technology accessed in the course to engage students in learning statistics.

Chapter Three: Methodology

This phenomenographical research aimed to explore varied lived experiences of behavioral, affective, cognitive, and social engagement of students in the AP Statistics course using a flipped classroom approach. Instead of quantitative data, this study examined in-depth qualitative data on students' experiences with active, collaborative teaching strategies and technology. This study sought to give students a voice to explain the learning experiences they respond to, which engage and/or disengage them in the classroom through the qualitative method, phenomenography. This chapter will start with the research design, rationale, a summary of the researcher's role in this study, and a description of the course activities. After that, human rights protection, sample and population descriptions, instrumentation, data collection procedures, and data analysis plans are discussed. The chapter ends with a discussion of validity, trustworthiness, and ethical principles driving the study.

Research Design

Qualitative research was considered the most appropriate methodology to collect the data because this study aimed to understand the students' perspectives of engagement in a flipped AP Statistics classroom and give students the opportunity to explain their experiences in their own words. Phenomenography was the qualitative method chosen to understand students' perspectives of their varied experiences in the flipped classroom (Marton, 1986). To understand the students' voices about their experiences with engagement in the AP Statistics flipped classroom, the following research questions were used:

- How do AP Statistics students experience engagement in the flipped classroom?
    - Which learning experiences help to engage students and why?
    - Which learning experiences contribute to student disengagement and why?

Phenomenography originated in the 1970s but did not appear prevalently in research until 1981. This qualitative method aims to develop the participants' experiential descriptions (Marton, 1981), and the different ways people experience phenomena (Marton, 1986). Each person does not uniquely understand a phenomenon; there are a distinct, countable number of ways (Booth, 1994). This research sought to understand the distinct, countable number of ways that the participants experienced engagement in the flipped AP Statistics course.

Phenomenography falls under the interpretive paradigm that believes reality is constructed socially, complex, and often changes (Glesne, 2016). Phenomenographers hold a non-dualistic perspective of experiences (Marton & Booth, 1997). In a nondualist ontology, the focus is on the world created by looking at the internal relationship between the world constructed by and imposed on the learner (Marton & Booth, 1997). There is no real external world and an internal subjective world; there is only one world, and we experience it differently because of our partiality (Marton & Booth, 1997). Phenomenography has its roots in educational research. In this study, the students all had the same classroom experience but had different perspectives and experiences on their engagement experiences. I intended to understand the collective ways that students experienced engagement.

Phenomenography is an interpretive paradigm with a non-dualistic ontology that has roots in education and seeks to understand the variation in how people experience a phenomenon. It is designed to improve educational outcomes with varied student results (Beaulieu, 2017). Phenomenography was the research method chosen to answer the research questions for this study.

Rationale for Phenomenographical Research Methods

This study followed a phenomenographical methodology developed to respond to educational questions concerned with learning. Specifically, it focused on understanding the variation in how AP Statistics students experience engagement in a flipped classroom. The objective was to understand how students experience engagement individually and the variation of engagement within the collection of interviews. Phenomenographical research findings are directly relevant to improving educational outcomes, especially where students have differing levels of success or failure in a class (Beaulieu, 2017). Teachers can improve pedagogically if they can understand the relationship between students, their peers, and the contextual learning setting. This research method was also chosen because there was a lack of qualitative and phenomenographical studies on engagement from a student's perspective; instead, most studies were mixed methods or quantitative studies (Bond et al., 2020). Quantitative methods can allow researchers to understand the engagement experience, a qualitative study explores engagement in more detail, and a phenomenographic study determines engagement through a variation in students' voices to inform instructional strategies used to teach AP Statistics.

Setting of the Study

The study was conducted at a traditional public school with a STEM program in Georgia. According to the Governor's Office of Student Achievement (2021), the school had 25% economically disadvantaged students, 10% students with disabilities, and 3% English language learners. The demographic breakdown of the school was 54% White, 12% Hispanic, 25% Black, 3% Asian, and 4% other ethnicities. The school had 7.8% of its population in the gifted program. The school's College and Career Ready Performance Index (CCRPI) was 82,

placing the school better than Georgia's average rating for schools but lower than the county's average rating.

Specifically, the students were chosen from an AP Statistics class of 17 students. This class was 41% male and 59% female. The demographic breakdown was 59% White, 12% Black, 17% Hispanic, 6% Asian, and 6% Other. Twenty-nine percent of the students were STEM students, and 41% were gifted. The enrollment was 71% juniors and 29% seniors. These students had chosen to take AP Statistics as an elective, which was not required in the math progression, and they took the course in one semester of eighteen weeks.

Consent and Recruitment

After obtaining IRB approval from the university and school district, I used a script to inform the students of my study (see Appendix A). The students were given parent consent forms and student assent forms if they wanted to participate. No student was included in the study without parental consent, and the students could have chosen to remove themselves from the study at any time with no penalties. A copy of the university parental consent form can be found in Appendix B, and the student assent form is in Appendix C. I recruited students by asking them to participate in the study and explaining my desire to understand their perspectives on the class activities, hoping that most would participate.

Sampling Technique

A purposeful sample of student volunteers was used for this study with the hopes that it would provide maximum variation. The sample in a phenomenography should be purposeful with maximal sampling (Green & Bowden, 2009). The students from my class were purposefully chosen as they all have experienced a flipped AP Statistics course from an instructor who had studied and understood engagement techniques in the flipped classroom. The point of maximum

sampling was to increase the possibility of variation in the experiences of the students (Akerlind, 2005b). The optimal sample would have students from different ethnic backgrounds and both male and female students. The sample should also represent students with different levels of achievement, STEM and gifted students, and non-STEM and non-gifted students. My convenience sample would optimally have maximal variation with students from different demographic backgrounds, different genders, and different levels of achievement; however, students were volunteers for the study and were only chosen from a population size of 17 students.

Participants

Of the 17 students, six volunteered to participate in the study. The students were all given pseudonyms to protect their anonymity. The six students were 33% male and 67% female. The demographical breakdown of race was 33% Asian and 67% white. Fifty percent of the students were not considered gifted or STEM students. The other 50% were all gifted students, and 67% were STEM students (see Table 4). All students received an A or a B in the course, so they were all high performing in an AP setting. This sample size was small but large enough to gather descriptions of the varying conceptions of student engagement.

Table 4

Demographics of Interview Participants

Participant Pseudonym	Race	Gender	Gifted/STEM	Grade
Amelia	White	Female	Gifted and STEM	Junior
Bella	White	Female	Neither	Senior
Oppenheimer	Asian	Male	Neither	Junior
Fiona	Asian	Female	Gifted and STEM	Senior

Willa	White	Female	Gifted	Junior
Aiden	White	Male	Neither	Junior

Flipped Classroom Teaching Methods

The flipped classroom model used in this study had students watching seven to ten-minute videos at home before class every other day with a short quiz to incentivize them to watch the video. The video was a quick introduction to orient them to the next day's learning. The video covered definitions, formulas for statistical concepts, and basic ideas about the next day's content. The quizzes contained fill-in-the-blank, multiple-choice, written response, and oral responses. There were approximately five questions on each quiz. When students returned to class the next day, they would work through a Stats Medic (2022) activity.

The Stats Medic (2022) activities were used daily to provide student activities for instruction. These lessons were scaffolded student-centered activities for students and were meant to engage students with relevant student-collected statistics (Stats Medic, 2022). These activities facilitated student learning through collaborative teams to gather and explore data. The lessons are scaffolded to direct students through formulas and necessary content knowledge. At the end of the lesson, the learning is consolidated, and important concepts are reinforced and formalized. The lessons highlight the difficult knowledge students learned within the videos. A detailed class schedule and the activities used to teach the students can be found in Appendix D.

As the teacher in the classroom, I organized the classroom activities, created the video content, and developed the formative and summative assessments. I helped answer questions when students worked within their teams on activities. I consolidated their learning after the learning activities on the main topics that were important for their success on the assessments and AP Statistics exam. At times, when the content was more difficult, I facilitated students

through the activity rather than having them work independently in teams. I chose the simulations and the statistical technology tools for students to use and assisted student learning of those tools. Technology tools used in teaching the students were applets on Stapplet.com, Desmos Classroom activities, AP Classroom, Quizizz, and various simulations found in the Stats Medic activities. At times I was the guide on the side and other times I facilitated direct instruction in the classroom to bolster the flipped classroom video instruction.

Data Collection Methods

Two different types of data were collected for this study, student journals and student interviews. Student journals were used to gather student engagement responses immediately after they experienced the activity. Semi-structured student interviews were done at the end of the semester to explore students' experiences with engagement further. This section will discuss the data collection process, including the timing and content of the research, student journals, the pilot study, and student interviews.

Timing and Content of Research

This study lasted seven weeks in the Spring semester of an AP Statistics course during the months of April and May of 2023. The full timeline for this study can be found in Appendix E. The interviews were conducted at the end of the semester, so the students were no longer actively watching the flipped classroom videos when journals were collected and students were interviewed. The students participated collaboratively in active lessons and activities to collect statistical data in class. Students journaled weekly on these activities from class during the seven weeks. The students were interviewed at the end of the seven weeks in the last week of May 2023.

Student Journals

All students completed the reflective journals through prompts in Google Classroom using Google Forms. These journals were collected weekly during the seven weeks of this study. Some student journals were collected before I received parental consent from the students. The IRB permitted the use of journals written prior to the study after receiving parental consent and student assent (A. Bain, personal conversation, June 21, 2022). The student journals asked students to reflect on their experiences in the classroom during the week and how they related to the learning in the class (see Appendix F).

Student journals were used for in-the-moment reflection for students. The journals were historical documents (Bowen, 2009) for students to record their engagement closely following the time of the activity. Through these journals, the students were able to reflect on activities that occurred during the week and share their feelings and opinions on how those experiences related to their engagement and learning in the classroom (Andrusyszyn & Davie, 1997). The journals provided me a glance at the students' perceptions of the activities in the class as they were occurring and added to the data about their engagement. The research journals were not sufficient by themselves to analyze student engagement, so all participants were interviewed to hear their voices and have them expand on their experiences with engagement.

Pilot Study

A pilot study was conducted to test and revise the interview questions. Four students who took AP Statistics last semester volunteered to help in this pilot study. I was able to practice the unscripted portion of the interview process to ask students questions that would lead them to explain their experiences with engagement through prompts and probing. All pilot transcripts were transcribed and analyzed for ways to write more probing questions.

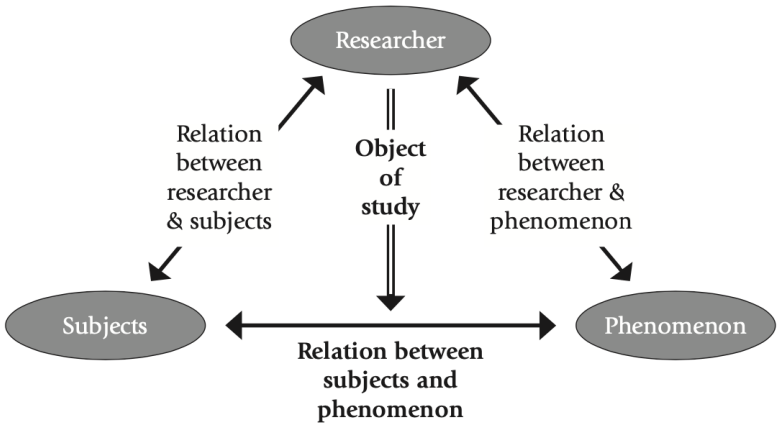
The pilot interview process also led to a rewrite of the original interview questions. The original interview protocol only focused on four questions, while the improved protocol was expanded to ten questions. This allowed the participants to be probed further into their experiences of engagement. Including more questions also gave the students more time to reflect on their experiences, and a richer transcript was collected for research. These interviews were not used as data in the study as the students had not completed the activities for a long time and were reflecting on material that was not recent for them. The pilot interviews refined my phenomenographical interviewing strategies to probe students for more detail of engagement during the activities they chose as fun and interesting during the semi-structured interview. The pilot interview led to a richer student transcript, more time for students to reflect on their responses, and provided more practice in developing interviewing skills.

Interviews

Phenomenographers want to understand the relationship between the phenomenon and the subject of the study (Bowden, 2005). Research is done from a second-order perspective; the focus is not on the phenomenon nor the participants, but the "experiences we are studying are oriented toward the world they are experiencing" (p. 210). As researchers, we need to bracket our judgments of the phenomenon and look at how the subject is experiencing everything, regardless of our beliefs of usefulness, validity, or functionality in the participants' responses (Marton & Booth, 1997). The researcher builds a relationship with participants during the interview process that is trustworthy and empathetic. The researcher also has an understanding and relationship with the research topic (see Figure 6). The interview process made it important for me to be the primary interviewer as I had intimate knowledge of the students and the AP Statistics flipped classroom that they experienced.

Figure 6

Phenomenographic Relationality (Bowden, 2005)



Note: Used with permission from Bowden. (J. Bowden, personal communication, February 16, 2023).

The knowledge of the AP Statistics flipped classroom, and the students allowed me to conduct one semi-structured interview with each student to understand their varied engagement experiences, which is the primary collection of data for phenomenography (J. Bowden, personal conversation, February 27, 2023). As their teacher and interviewer, I had a semester to develop rapport with my students. Rapport was important as it allows access, and trust helps the students to share their stories (Glesne, 2016). The rapport with my students and knowledge of my students' experiences helped me to make the most of one interview. All student interviews were scheduled only after completing their final projects in the class, and grades were finalized in the grade book. The students did not seem concerned about their grades being finalized, but I wanted to be sure there was no chance for them to feel pressure to participate or to answer in a

disingenuous way. Rapport and knowledge of my students helped one interview to gather suitable data on student experiences in the AP Statistics flipped classroom.

All students were only interviewed once in this study. If students were given subsequent interviews, the structure would mimic the first interview, which may cause students to adjust their answers as they became familiar with the format (J. Bowden, personal conversation, February 27, 2023). Each interview lasted, on average, 40 to 50 minutes. The interview process was done only once to elicit genuine answers unaffected by previous interviews.

Phenomenographers use semi-structured interviews to ensure they are prompting the students on the how and the why of their experiences rather than the what (Bowden, 2005). Individual interviews were used to hear the students' perspectives on engagement and to give them a voice in engagement data. All students were asked the same questions found in the student interview protocol (see Appendix G). The questions did not discuss engagement directly unless the students brought it up. I did not lead the interview in a specific direction, but I responded and asked the students to talk more about their responses. I listened actively and prompted the participants to expand on what they had said (Akerlind, 2005b). The probes and unstructured portion of the interview process were used to help students describe their engagement more fully and focus on "why" rather than the "what" during follow-up questions and did not focus on the actions of the participant (Akerlind et al., 2005). It was necessary to respond with proper follow-up questions to elicit the responses that answered my research questions while I practiced impartiality and bracketed my understanding and meaning of engagement to focus strictly on the participants' meaning.

Data Analysis Strategies

Two different analyses were conducted in this research: phenomenographical analysis of the interviews and thematic and content analysis of student journals. The following section will describe the analysis of the student journals and interviews.

Phenomenographical Analysis of Interviews

Data analysis began after all participants were interviewed (Green & Bowden, 2009). Interviews were transcribed verbatim. Phenomenographic analysis is an iterative process of reading interview transcripts. The first time reading through transcripts, they were read to determine if a meaning occurred throughout all the transcripts while keeping in mind the contextual meanings within each transcript (Green & Bowden, 2009). This study's phenomenographical analysis focused on understanding engagement through the participants' experiences.

Using an iterative process to read through the transcripts, I looked for supporting and opposing examples of engagement in the transcripts (Akerlind et al., 2005). I read through all the transcripts approximately four more times, taking breaks to look at the data with fresh eyes and possibly a new perspective (Akerlind et al., 2005). I used open coding to break apart and look for concepts evident in the data (Corbin & Strauss, 2008). This reduced the data to sentences, phrases, or paragraphs of meaning. When performing this reduction, I practiced epoché or bracketing, focused on descriptions rather than explanations of the experiences, and ensured all descriptions were equally important (Bruce, 1994).

There is no prescribed way to analyze the data in phenomenography. The process I followed in my data analysis pattern was:

1. I familiarized myself with the data and the details by reading entire transcripts twice before coding through transcription and making sure Otter.ai accurately recorded the transcriptions. The second time was without coding and reading for themes and determining the conceptions of engagement, focusing on the students' meanings, and bracketing my experiences and research.
2. I started to code the data with Atlas.ti software to look for similarities and meanings within all the interviews.
3. I looked over the codes and meanings in the transcripts and started to determine codes with similar meanings, condensing codes into similar themes.
4. I determined how codes can be combined into categories of description.
5. I separated the meanings of the interviews and created the categories of description.
6. I discussed the categories of description with another researcher as a devil's advocate to be sure I was true to the results of the transcripts. This researcher is known as a peer debriefer; and he proposed alternative interpretations of my analysis of the data (Morrow, 2005).
7. I labeled the categories and made sure they were distinct. I continued to re-read to ensure the categories were true to the students' meanings in the transcripts.
8. I determined the hierarchal relationship between the categories of description to form the outcome space.

The analysis aimed to create categories of description (Akerlind, 2005a; Green & Bowden, 2009; Marton, 1981, 1986). The experiences as individuals and between individuals are developed into categories of description to capture the distinctive ways participants experience the phenomenon (Marton & Booth, 1997). The categories of description make up an outcome space that

hierarchically describes the relationship structure between the categories of description (Marton & Booth, 1997). The outcome space should show a logical relationship that captures the critical variations and structure of the distinct categories of description (Larsson & Holmstrom, 2007). The outcome space can be displayed as a table or diagram, which shows how the categories of description fit together to make up the phenomenon for the participants in this study (Yates et al., 2012). The categories of description for engagement, outcome space for engagement, and themes of disengagement resulting from this data analysis are discussed fully in Chapter 4.

Data Analysis of Student Journals

Thematic analysis with an *a priori* coding structure was used to analyze the student journals. The thematic analysis looks for themes through reading and re-reading the passages (Bowen, 2009). The student journals were coded using an *a priori* codebook (Saldana, 2021). The *a priori* codebook was developed through the data analysis of the student interviews (see Appendix H). Using the codes created through the phenomenographical outcome space, I looked for consistent themes between student interviews and journaling. The themes that were discovered in my phenomenographical analysis supported the theoretical framework for this study.

The steps followed when coding the student journals were:

1. I loaded the student journals into Atlas.ti with the student interviews and coded the interviews using the codebook from the phenomenographical data analysis.
2. I re-read student journals with fresh eyes over a few days to ensure the students' meanings were the results of the data analysis.
3. I condensed codes into similar meanings of engagement and disengagement.

4. The peer debriefer was used to be sure my analysis stayed true to the students' meanings (Morrow, 2005).

I compared the results to the phenomenographical analysis to determine which themes were consistent through both data and which themes were new. The content and thematic analysis of the student journals will be discussed thoroughly in Chapter 4.

Role of the Researcher

My role in the research was teacher-researcher. Dewey (1910) called for teachers to be reflective and thoughtful. He described reflection as looking at a topic in all possible lights and seeing all the facets, like picking up a stone from the ground to see what it is hiding or looking at what is underneath. Dewey (1910) called for teachers to be thoughtful and to pay close attention to their practices. Reflection is a process that teachers should regularly examine and evaluate their practices to improve in the classroom (Shandomo, 2010). As a teacher, reflecting on teaching practices and strategies is vital. Teachers who reflect on their teaching practices become competent pedagogy practitioners (Dewey, 1910). Through this research, in addition to adding to the knowledge about engagement, I also reflected on my teaching practices to keep students engaged in AP Statistics.

As a teacher, I wanted students to be actively involved in learning, not passive learners. I used the flipped classroom model to give students maximum time to be active in their learning and work collaboratively with peers to synthesize their learning. I studied best practices in the flipped classroom for years, and my practices evolved and adapted based on that research. As a proponent of the flipped classroom, I realized my bias toward this form of teaching. In my data analysis, I carefully allowed students' perceptions and experiences in the flipped classroom to be highlighted in the research findings and engaged in reflexivity. A key component of reflexivity is

for the researcher to assess the relation to the participants transparently (Dodgson, 2019). I desired to understand and gave students a voice in the flipped classroom strategies that engage them.

In this phenomenographical study, I chose to do what Glesne (2016) refers to as "backyard research" (p. 26). Glesne warns the novice researcher that while this may seem enticing and straightforward, there are many pitfalls to this type of research when it is qualitative. Glesne suggests that a researcher may learn more in an environment that they are unfamiliar with. However, sometimes teacher research is best done in the "backyard" (Glesne, 2016). Researchers not affiliated with the organization sometimes have difficulties accessing data or recruiting students. Backyard research can be valuable but needs to be entered thoughtfully.

As a researcher, I had biases from having a familiar relationship with my participants. I wanted to understand my students' perspectives on engagement fully. I was willing to accept the good and the bad in the results to grow as a teacher. I hoped my research would contribute to research aimed at understanding the practices that engage students; therefore, I presented the results fairly and bracketed my assumptions. My intention for this research was not to promote my bias but I gave students a voice and tried to understand their perspectives. I used established strategies to address the study's trustworthiness. I kept a researcher's journal to self-evaluate, critically reflect, and practice reflexivity. This helped me to make sure that my choices were true to the students' conceptions of engagement.

Trustworthiness

The trustworthiness of this study was extremely important. The four major components of trustworthiness as found by Guba (1981) are credibility, transferability, dependability, and

confirmability. Tasks that can account for credibility include triangulation and member checking. The student journals were used to triangulate the engagement data and provide another source that bolsters the data found in the phenomenographical analysis of the interviews. The students' journals were collected over a prolonged period throughout the seven weeks of the course, which is another task that can contribute to the credibility of the study. After the interviews had concluded, I had candid conversations with every student to do member checking asking students to reflect on the class as a whole and their thoughts on the flipped classroom methods. These tasks contributed to the credibility of the study.

To address transferability, Guba (1981) stated a thick description of the context of the study and purposeful sampling is important. Cope (2004) asserted that the phenomenographic researcher should provide a comprehensive account of the study's methodology, including the characteristics of a purposeful sample; a justified design of interview questions; the researcher's approach to data analysis; detailed data analysis method; processes to control and check the researcher's interpretations; results presented transparently; and categories of description should be fully defined with participant quotes to support them. I have presented a literature review that describes my knowledge of students' engagement through the flipped classroom, in math classes, and with technology. I have justified my sampling method that meets the expectations of a phenomenographical study. I have provided a thick description of my data analysis procedures and setting so that other researchers may determine the transferability of my data.

To establish dependability, I shared my data analysis and findings with my dissertation chair to gain valuable insight and external reflection on my work (Glesne, 2016). I worked with John Bowden, a retired professor from RMIT University in Australia, who is an experienced phenomenographer, to create interview protocols that meet with standards of phenomenography.

I analyzed my interviewing practices and ensured my questioning aligned with phenomenographical practices with his help. I used the help of an approved CITI researcher, Dr. Curtis Gile, to ensure my data analysis was true to the transcripts and the students' conceptions of engagement. By having another researcher assist and check my analysis of the data and leaving an audit trail of my steps taken throughout the process, the process I used can be considered trustworthy.

The final component of trustworthiness is confirmability (Guba, 1981). Confirmability was established using reflexivity (Guba, 1981). and is related to the belief that the results are based on the participants' responses, rather than the subjectivity of the researcher. Reflexivity is practiced through a researcher's journal and debriefing with peers. To practice reflexivity, I kept a journal while analyzing the data and participated in conversations with Dr. Curtis Gile, who analyzed and played devil's advocate, before I had determined the outcome space. The student journals also contributed to the triangulation of the data and confirmed the results of the student interviews.

Ethical Principles Driving the Study

The *Belmont Report* was published in 1979 by the National Commission for the Protection of Human Subjects and Behavioral Research. The *Belmont Report* determined three ethical principles to be followed when involving humans in research: respect, beneficence, and justice (Glesne, 2016). The first ethical principle is the principle of respect, informed and voluntary consent (Glesne, 2016). For my research, I will obtain consent from the IRB, consent from my school and county, informed consent from the parents of my participants, and consent from my participants. I respected the university, school system, parents, and participants' rights to be informed and give consent to the research being conducted.

The second principle of beneficence states, first and foremost, that the researcher will do no harm. As a researcher, I am charged with protecting the anonymity of my participants (Glesne, 2016). I am my high school's only AP Statistics teacher, but my entire class is not in my sample. I have used pseudonyms on all example quotations from my students. I have practiced confidentiality when discussing my research unless a mandatory reporter situation arises. I provided my participants with a safe, trustworthy environment where they shared their authentic engagement experiences without fear. I did not discuss the research within my class before the research occurred to avoid inadvertently influencing student responses.

The third principle of justice focuses on sharing research benefits and burdens (Glesne, 2016). The research did not exploit vulnerable populations, nor did it seek to exclude vulnerable populations that would benefit from the study. I used the experience and knowledge gained from the students in a semester but did not abuse my relationship with them. I was faithful to my research and ensured the portrayal of the students' experiences as they described them.

Summary

This research explores students' engagement and disengagement experiences in a one-semester, flipped AP Statistics course using a phenomenographic, qualitative approach. The participants are AP Statistics students with a mix of demographics from a traditional public school in Georgia. The qualitative data analyzed includes student journals and interviews. Open coding was used to analyze the student interviews (Corbin & Strauss, 2008). In this phenomenographical analysis, the open coding looked at sentences, phrases, and paragraphs of meaning (Corbin & Strauss, 2008) that were broken into categories of description and formed an outcome space that hierarchically describes the relationship structure between the categories (Marton & Booth, 1997). The outcome space describes students' engagement, but elements of

disengagement were also found during open coding. The student journals were analyzed with an *a priori* codebook (Saldana, 2021). The thematic analysis (Bowen, 2009) was compared against the coding found in the phenomenographical analysis, and similar themes were found. I took on the role of teacher-researcher in this research as I taught the students, interviewed the students, and analyzed the data. In this research, I hope to improve my teaching practices and contribute to the research on student engagement. Strategies were used to ensure the trustworthiness of the data and results, including external validation (Glesne, 2016) and transparency of my methods (Cope, 2004). Ethical principles of respect, beneficence, and justice were followed (Glesne, 2016). The results of the qualitative analysis will be discussed in Chapter 4.

Chapter 4: Findings

This phenomenographic study aims to explore student voices of their varied lived experiences of the multidimensional construct of engagement in a flipped AP Statistics class. This analysis seeks to determine what students believe are effective strategies, activities, technology tools, or design features that engage and disengage them in the AP Statistics classroom. The questions driving this research study were:

- How do AP Statistics students experience engagement in the flipped classroom?
    - Which learning experiences help to engage students and why?
    - Which learning experiences contribute to student disengagement and why?

This chapter begins with an overview of the research's participants. There will also be a discussion of the findings of the phenomenographical analysis of student interviews on engagement, the themes of student disengagement that evolved from the analysis of the interviews, and the thematic analysis of the student journals.

Setting

The setting is a large public high school in Georgia. I taught two sections of AP Statistics course this year, one in the fall and one in the spring. The flipped classroom method was used in both semesters, and the classes were taught similarly in both semesters. Some variations occurred due to time constraints and student differences in the two semesters, but the flipped classroom structure remained constant.

Outside of class, the students watched quick seven- to ten-minute overviews of the learning for class the next day. I provided guided notes for students to fill in as they followed the videos to help with structure, but they were not required. Short quizzes were given on each video to engage students and provide accountability for students. The quiz questions could be fill-in-

the-blank, drawn answers, audio answers, free-response, or multiple choice. The students were given the flexibility to access the videos a week before they were due. Students were not expected to have mastered the material in the videos by class but to have watched them so that they had a baseline understanding of the standards. The students had not had to watch videos for about a month since they were preparing for the AP exam and completing a final project for the class at the time the study was conducted. In this flipped classroom, the students are tasked with the direct instruction portion of the learning to largely be done through videos before class that had quizzes to provide an incentive for engagement with them.

Students attended class for a 90-minute block daily during the fall semester. The in-class active learning activities were from Stats Medic (2022). These activities allowed students to collect data and apply data to learn statistics. Some activities were done in collaborative groups, and some as a class. The delivery method depended on the task and the importance of the concept learned. Students were provided with open structured notes for all activities done in class. The statistical concepts they learned were summarized at the end of the activity including an example of the concept learned in class. An example of a Stats medic activity the students mentioned as engaging is presented in Appendix I. In most classes, the students were given some class time to work on extra multiple-choice and free-response questions collaboratively or individually (their preference) to practice their learning further. The activities and the practice questions were designed to teach the content and prepare the students for the AP Statistics exam at the end of the year.

In addition to the daily classroom activities, the students were given several culminating activities to apply their knowledge throughout the semester. The first was a gummy bear experiment (see Appendix J). In this experiment, students built a catapult and launched gummy

bears, collected data, and wrote up an analysis of their data using graphs and descriptive statistics (see Appendix K). Another activity involved students creating two surveys– one that deliberately had a bias and another that did not have the bias. The students randomly assigned the treatment of a biased survey or an unbiased survey to a group of participants. With the results, the student analyzed the difference in their responses with statistical inference. Students reported whether the bias showed significantly different responses than the unbiased surveys. The final project was a choice board (See Appendix L). The students could work in pairs, groups, or individually on various activities. These activities were meant to culminate experiences for the students and allow them to apply their knowledge. All these activities were provided as a real-world opportunity to apply their statistical knowledge in a manner that was not a high-stakes test or quiz.

Findings

The student interviews and student journals were analyzed for their content. Four categories of description were determined to describe engagement in students' interviews: activities that allow students to be social, activities that activate student cognitive thinking, activities that increase students' positive emotions, and student internal motivation. These categories are represented in the outcome space diagram showing how the categories of description are related and describe experiences that engage students (see Figure 7). The outcome space, the categories of description, and the codes for engagement and disengagement found in the data analysis will be discussed further in this section.

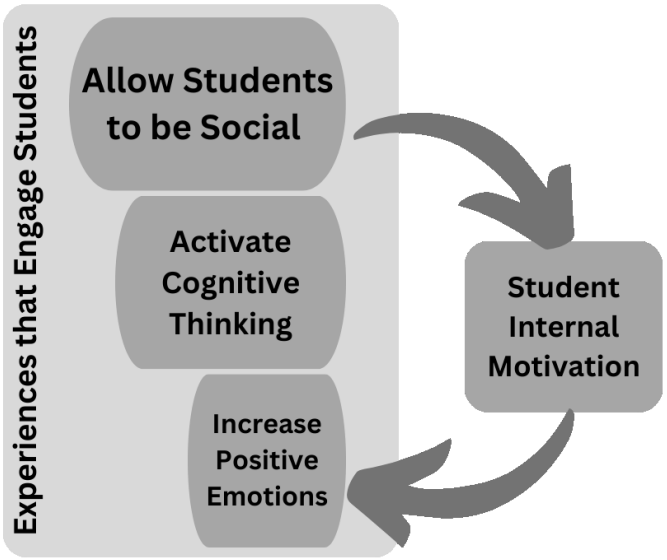
Findings from Phenomenographical Analysis

During open coding and phenomenographical analysis, the student interviews describe their experiences with engagement in the flipped AP Statistics classroom. The students described

engaging activities as ones that activate their cognitive thinking, allow students to be social, and increase students' positive emotions. The interview transcripts found that students have internal motivation to help engage with tasks and that engagement elements can help activate their internal motivation. The categories of description make up the phenomenographical outcome space and answer the first sub-question: Which learning experiences engage students and why? The following is the discussion of the categories of description that form the outcome space.

Figure 7

Outcome Space for Phenomenographical Analysis of Student Interviews of Engagement



Category One: Allow Students to Be Social

Students worked in teams daily on their in-class activities or the multiple-choice and free-response practice. The team could be comprised of all the students in the class working together to collect data or a small group of no more than four students working together on tasks, projects,

quizzes, or example problems. The groups of students were self-selected and, in most cases, comprised of students that knew each other before the start of the course. Students worked well together and often without my assistance.

Student interviews frequently mentioned that they prefer to be social when working on activities; 72 of the 278 phrases mentioned social engagement as important. All the students interviewed mentioned aspects of their teamwork when asked about interesting and enjoyable tasks. Four codes emerged as students described how they engaged in a social setting: comfort in self-selected groups, more knowledgeable other, trust in the group, and collaboration through technology.

Comfort in self-selected groups. I allowed students to pick the teams that they used during projects, group quizzes, and classroom activities. I trusted students to make their groups because they were advanced juniors and seniors. I also did not want them to worry about contacting each other outside class when working in teams on longer-term projects.

Thirty-five of the 75 quotes were coded comfort in self-selected teams. Being in self-selected groups helped students feel comfortable when they worked together and promoted student engagement. This was evident in this quote by Fiona:

> Most of the time, when you are working with people, you're more likely to be engaged in what you are doing. But, at the same time, if it's like people you don't want to work with, you probably won't be as engaged.

Every participant implied that teams of friends or people they knew before class helped them communicate ideas easily. The teams were able to form naturally without the students worrying about who their team members would be. Willa's quote mentioned this idea, "I have somebody I know I can work with. So, it's not like I had to randomly make friends for group projects, so that

was nice." The interviewed students liked choosing their teams and felt comfortable when they knew their teammates, which led to more engagement when they worked in their teams.

More knowledgeable other. Five of the six participants mentioned that they worked collaboratively on solving problems together, and 17 of the 75 coded sections referenced a more knowledgeable other. Students relied heavily on their partners in group work to understand the content; working in teams provided opportunities for the students to have discourse with each other. Students learned from each other when they did not understand the content. They also felt they could contribute to the conversation to help others. Bella explained:

> If I was confused about something, one of my partners would know how to do it, or if they were confused about something, I might know how. So, then we would teach each other in a way.

The participants appreciated the ability to communicate with each other to gain a new perspective on their learning, as shown in this quote by Willa: "Especially when you don't know what you are doing or you like forgot something, there's always someone to bounce off of." Oppenheimer and Fiona had similar statements referencing bouncing ideas off their teammates. The students considered their teammates and themselves able to teach each other hard concepts and to learn more because they were able to communicate when discussing new or difficult topics.

Trust in the group. Five out of the six participants stated they trusted their teammates in the interviews, with 17 of the 75 coded sections referred to this code. Students built trust among their team members and knew they could rely on them during challenging tasks. One of the quotes by Bella made this evident, "And so I really trusted them, I felt like with all of us

together, we had a good understanding of what we were doing." The groups also felt like they could trust their teammates not to judge them when they asked questions. Willa said,

> But when they are helping you, they're kinda egotistical about it and like kind of rude and like: That's how. How do you not know that? Are you stupid? Nobody was like that in my group. It was very like this is how you do it. It's just like nothing to worry about.

Another way that students discussed trust in their teammates was through the division of labor on group projects. Oppenheimer often referred to the division of labor with his partner in group projects and stated, "We're able to divide the work up, and it was much easier. So, I felt great having a partner." Aiden mentioned something similar in his interview about the group working well together and roles naturally being assigned. The students found their roles naturally and trusted teammates to do their part to complete a project or challenging task.

Collaborations through technology. When working in teams on long-term projects, three of the six participants mentioned valuing using technology to collaborate, whether synchronously or asynchronously. A quote from Amelia demonstrated this,

> That was something we could do through Google Slides because it's updating on the slide versus something we had done on paper. If we don't have a copy or it's not constantly updating, the other person can't see it.

Collaborative technology tools were useful when working on group projects. Fiona and Oppenheimer mentioned technology helped them to work synchronously from different locations. They mentioned calling each other to collaborate on a team document outside of class. Some students used this technology to work asynchronously, and others preferred to call each other and work synchronously on the same document in different locations.

Summary of category one. Student interviews showed that working collaboratively on projects, activities, and quizzes was important. By working in teams, they helped each other to learn and understand the material. Students who worked in self-select teams felt comfortable and built trust quickly. Collaborative activities engaged students. Aiden demonstrated this idea:

> Working in small groups provides more excitement. By this time, I'd sat through two classes. I just sat there and either watched the board or read a passage or excerpt from a book. So, working in small groups and getting the chance to interact with classmates is like a reprieve.

Students engage in activities that allow them to be social when they are learning.

Category Two: Activities that Activate Students' Cognitive Thinking

Every participant interview had quotations that showed engagement in activities that activated their cognitive thinking, and 68 of the 278 coded quotations referred to this category. The message from every participant was that for students to be engaged, the topic needed to hold their interest. Their interest helped them to remain diligent in completing difficult tasks. The codes that make up this category are the application of knowledge, application to the real world, active learning, perseverance, and instant feedback through technology.

Application of knowledge. Five of the six students mentioned that applying their knowledge to activities was engaging. This comprised 21 of the 68 coded quotes. The students appreciated applying knowledge differently than homework, quizzes, or tests. Aiden summed this idea up well:

> I think it makes it more fun because it's kind of different than what we normally do at school in terms of packets and paperwork and everything. So, when we do get a chance to see and work with what we're talking about. It makes it more engaging.

The students mentioned that projects were engaging when they could apply their knowledge outside the classroom. Amelia said, “That was cool because it let us take stats outside the classroom.” When they can apply their knowledge outside the classroom, students connect the importance of the topic to their learning. Oppenheimer’s quote shows this:

> A lot of kids say, when will we actually use this? The stuff we learned in class? and don’t tell the math teacher. When will I actually use this applied math? And this is a scenario where you would use it, or if you go into the field like you would use it.

When students were involved in activities to apply their knowledge, they were engaged with the activities.

Active learning. The students preferred actively creating content. All six participants mentioned active learning as important to their engagement, and 18 out of 68 responses were coded as active learning. Aiden described active learning as “(something) tangible that we could actually see it happen in front of us rather than seeing it on paper.” Aiden also stated that he was engaged when actively participating, which helped him remember the content they learned. “Actively learning for almost the entire duration of the class (90 minutes). It has a mainstay in my brain, and I can remember that vividly.” Bella also echoed Aiden’s sentiment: “I feel better when I’m actually doing something other than when it’s just like notes because it helps me to remember.” Amelia stated that active learning stood out because “it is fun to build something. That’s always really engaging and interesting for us to do. That is why it stood out.” The class activities that enabled students to be active in their learning were engaging to students and helped them to remember the content better.

Application connected to the real world. Five of the six participants’ interviews mentioned that activities that were connected to the real world were engaging, making up 12 of

the 68 coded quotations in this category. Students attributed these to something a real statistician would do. They felt like they were applying their statistical knowledge in the real world. Amelia stated,

> I really liked the nine weeks project on bias because it allowed us to explore a topic we wanted to. We got to personally go out into the world, ask people what they thought, and purposely create bias to help experiment with statistics in the real world. So that's fun.

Fiona said something very similar to Amelia in her interview. Aiden stated, "It gave me a first-hand real-world scenario, and when I could use it." Oppenheimer pointed out that real-world studies are being published, and they could be consumers of these studies due to their statistical knowledge. When activities were tied to a real-world application of their knowledge, students found value and were engaged in these activities.

Opportunities to create new data. Five participants' interviews had the code that students engaged in tasks that allowed them to create data; this was in 11 out of 68 quotations. The students stated that the data they created was more meaningful to them and gave them context within the activity. Amelia said, "It wasn't just data that we found online that we just kind of had to believe it was data. We got it ourselves and saw that this is actually statistically significant for real." Fiona stated, "It wasn't like random numbers that had already been pulled for us to just work on in class." By creating their data, the students could follow their data points in the activity; this helped with context and understanding of the material. Willa said, "But when it is your own numbers, and you're looking at it like, oh, that was my result. Let's see where it places in this (graph)." By having students create the data being used in the project, they have context for the data and can understand concepts better, which helps the student engage in the activity.

Instant feedback through technology. Four participants had quotations coded instant feedback with technology; this represented six of the 68 coded phrases. The students discussed how technology helped them to see and analyze data quickly. Students used Stapplet to create graphs for their projects. This website provided instant graphs and data analysis of the data they entered. Aiden said, "It was interesting putting all the data into Stapplet and seeing all the graphs. The fact that we would see the graphs was better for learning." Stapplet allowed them to take easy snapshots of the screen to put into their projects. Amelia's sentiments were like Aiden's. She added, "(Stapplet) was so much easier to do than drawing it by hand or honestly even using our calculator because you can't take a screenshot on a calculator." Using technology allowed students quick access to the results so that they could focus on the data analysis.

Students were assigned mini quizzes in AP Classroom to help them study for the AP exam. The mini quizzes focused on practice with around five to ten multiple-choice questions. The mini quizzes provided students with instant feedback on the correct answer but also gave students feedback on why an answer was incorrect. Although I had also provided multiple choice practice with answer keys throughout the year, Amelia mentioned that these quizzes in her interview:

> Anytime you click on it, it tells you this is correct and gives an explanation. It also tells you why your answer is wrong. It tells you this is wrong because (insert reason). I think that is helpful because whenever I answer questions, my issue isn't why your answer is right. It's why my answer is wrong. I understand, and you're going to explain it, so it makes sense. But why is what I put incorrect? What kind of train of thought maybe led me up to that? I think the College Board really helps you identify what you were thinking when you chose that (wrong answer).

She elaborated, “Sometimes I understand, but maybe not as much as I’d like and not to the point where I feel like we need to have a whole discussion, like a class discussion, about it.” With this use of technology, students receive instant feedback on right and wrong answers that allow them to think critically through the choice they made and how to improve in the future when they get the same type of question.

Summary of category two. When students engaged in active learning, they cognitively engaged with tasks that allowed them to apply their knowledge or apply real-world concepts. Data analysis involves dealing with data and in some cases, a large amount of data. The students could concentrate on the cognitive part of their engagement due to the instant feedback from technology on graphs, data calculations, and multiple-choice questions. Students could also connect with data when they actively collected it, so they understood where it came from and could apply meaning to their results.

Category Three: Increases Students’ Positive Emotions

The next category of description emerging from student interview transcripts was activities that increase students’ positive emotions. This comprised 41 of the 278 coded sections of the transcripts. The emerging codes in this category were tasks they enjoyed, tasks that challenged them, and tasks technology made easy.

Tasks that students enjoyed. All the students had portions of their interviews coded with this category, representing 22 of the 41 codes. Students appreciated activities that were achievable and did not feel like work. When the task was enjoyable, they were willing to put effort into it. Fiona mentioned this in her interview, “If we have something that’s fun for us, then we’re more willing to do it than something our school made us do.” Bella mirrored this sentiment when she said, “I felt like we were really engaged because it was fun, and it helped me

learn more because I was just having a good time with it. So, I didn't feel like I had to do it." When the students enjoyed the task and had fun, it helped them engage with the task, and it didn't feel like work.

Tasks that challenge students. Four participants mentioned that the challenging activities gave them a sense of accomplishment, and it was coded 12 times. Amelia and Oppenheimer referred to the trial-and-error process that helped them to stay engaged and achieve success. Amelia said, "trial and error really made me stay engaged." when she discussed creating the catapult in the gummy bear experiment. Amelia went on to say:

> If we had been told just one way to do it, we wouldn't have had to try different options or different ways of doing it. We didn't initially start with the catapult idea that we had. We initially started having the rubber band too high up, and it didn't give us the right amount of tension for it to actually fling the gummy bears. Trying that and trial and error troubleshooting is what gave us the best result for our catapult. If we had initially been given the best format of a catapult, we wouldn't have had to have tried to identify what that was going to be.

Fiona indicated, "Being able to complete something we had found difficult gave us a sense of accomplishment, and we were pretty proud of the project that we created." Bella mentioned that although the challenging tasks were hard, they were helpful in preparing for the AP exam. Challenging tasks gave students a sense of accomplishment and engaged students.

Tasks that technology made easy. Three of the participants mentioned that technology was helpful and made tasks easier for them to complete. The students most often used graphing calculators in the class to analyze data. Stapplet was a website they used for quick data analysis and dynamic graphs. The students liked the ability to use technology to create data quickly and

graphs easily. Oppenheimer said that throwing it in the calculator was the "easiest part of statistics". The students also used Google Sheets to look at data from their bias survey projects. Oppenheimer also said, "It (Google Sheets) was easier to see the data and do the math in there. You highlight a column, input the function, and work on it." The students also used Google Slides and Canva to create dynamic displays of their projects. Fiona said, "We used Canva to create infographics… and seeing the different colors on the bar graphs made it more engaging." The technology made creating graphs and presentations easier, leading to student engagement.

Summary of findings from category three. The tasks that gave students positive emotions were tasks they had fun doing. When they were having fun, they felt like they were not working. This made working on tasks for a long time or outside of class time easier. When students overcame a challenging task, it helped them to feel a sense of accomplishment. The students liked the ability to use technology to help them to present data and represent their data in a visually pleasing way on projects.

Category Four: Student Internal Motivation

All participants' interviews had sections that were coded as student internal motivation. This made up 51 of the coded sections. The three codes that fall into this category of description are perseverance, choice, and self-efficacy.

Perseverance. Five of the participants had sections coded perseverance, making up 26 of the 51 codes in this category. This was usually mentioned when students discussed a challenging task, but the phrases referred to their desire to do well despite the challenges. When students' phrases were coded as perseverance, they talked about a struggle that they stuck with and tried different approaches. Fiona said, "I remember specifically how we were struggling." She said this when she described doing the survey bias project. She also said, "I was constantly

asking my partner about the actual statistics for our presentation or putting it into another website, so it looked fancier." Oppenheimer stated, "Even though our experiment had some variables that made it confounding in the experiment, we wondered how to improve on it." Amelia discussed perseverance when she was talking about making her catapult for the gummy bear project, "Ours wasn't going that far, so we kept on trying until we made it better… we wouldn't have figured it out if we didn't keep failing." Willa explained perseverance as her desire to do well and get good grades. She also stated, "There's usually something like it's just some specific thing I'm missing that I have to figure out. So, I keep working, looking at my work, looking at other people's work, talking to people about it." These students persevered through difficult challenges due to their internal motivation, and that also is driven by their engagement in the topic.

Choice. Five participants had 16 coded sections that stated choice in a project was preferred and motivated them because it piqued their interest. Amelia referred to the gummy bear project when she was talking about choice. She said:

> It's engaging because it gives us a lot more freedom. We didn't necessarily have – this is how you have to build the catapult. We had the opportunity to make it with the resources and figure out how we wanted to make it work.

Amelia also liked the ability to choose the nine-week project. Oppenheimer said, "It felt good to be able to decide on what to do for me and my partner." when he also discussed the nine weeks project. Fiona also expressed that choice was important when she said, "I really liked the nine weeks project on bias because it allowed us to explore a topic we wanted to." Willa articulated, "I like being able to choose. I could choose the assignments that I do the best on because I knew

what I was doing." when she discussed the final project. Student choice motivates students and helps them engage more with the material.

Self-efficacy. Three of the participants had themes of self-efficacy in their transcripts, making up the remaining 9 of the references in this category. These students mentioned that the projects and assessments were easier when they were confident and knew what they were doing. Some students mentioned they had confidence because the projects were done after the learning occurred in class. Amelia said:

> (I) was much more confident doing the project. I knew how to do the material because I had practiced it enough. So, then it was much easier to apply, and I didn't have nearly as many questions as I did when I was initially learning it.

Oppenheimer and Willa explained that knowing what they are doing helps to keep them engaged. Oppenheimer stated, "If you know what you are doing, then it keeps you engaged. But if you're confused on it, then it would kind of dissuade the person doing it." Willa said, "So a lot of the projects were a lot easier than other things because I knew what I was doing with them." Students stated in their interviews that it was important to be confident in the material to be engaged and motivated to work on projects.

Summary of findings from category four. Students' internal motivation was affected by their ability to choose the topic they worked on and their self-efficacy with the material they were studying. When the students persevered through challenging topics, they were driven by their internal motivation to do their best and get good grades. Internal motivation helped to drive their engagement in the class and their engagement also drove their internal motivation.

Findings from Student Journals

Students were asked to journal once a week during the last seven weeks of the course. During this time, the students were focusing on a project for a unit they completed on linear regression, binomial and geometric distributions, reviewing for the AP Statistics exam, and completing their final project. The journal entries were short, but some codes developed that supported the findings from the phenomenographical analysis.

Allowing Students to be Social

In the thematic analysis of student journals, the students mentioned the group project the most, but that is because they worked on this project for two weeks during the collection of the journals. The students were grateful for the slow pace of the course at this time and the ability to work in groups. Fiona stated, "It has been nice because we can work on the final project in a more relaxed manner." Student journals also mentioned the group quiz that was given. Fiona mentions, "I liked being able to work on the quiz with a group because it was an opportunity to realize some of my mistakes and correct it with my peers." Bella said, "It helps me a lot to understand the material better by working with someone else to figure out the answers." These statements support the idea that students value a more knowledgeable other within the group. This theme supports the phenomenographical analysis that students were engaged when they were given the opportunity to be social and learn from one another.

Guided Notes over Open Notes

The second most mentioned topic was the change in the class notes. This unit needed to move fast due to the time constraints of the remainder of the semester and the percentage of the AP Statistics test questions that refer to this topic. We used notes that Skew The Script created that are available for free use for the unit (Skew The Script, 2022). Part of these notes are in Appendix M. These notes are presented as direct instruction with a guided note packet, where students only have certain words or phrases to fill in. The lessons had students discussing relevant real-world topics with direct instruction. The Stats Medic (2022) notes we had used for the remainder of the semester are more open-ended and require students to write a lot at times. Some students preferred the Skew The Script (2022) guided notes to the Stats Medic (2022) activities, but all students preferred guided notes over an open note strategy. This was evident in the quote by Aiden, "This week we took notes using an interactive packet. The packet was very useful to go back and review information such as stems for interpretations. I personally don't like taking notes, so the fill-in notes are very favorable." Oppenheimer, Fiona, and Bella also stated they preferred a guided notes format. Bella said,

> I like how we used the new notes that were fill-in-the-blank. They were a lot easier for me to keep up with. Often in class, I get behind in writing all the notes, so this week's packet made it a lot easier. It was also a lot easier because they were very organized.

When students need to take notes to learn a topic, which they all know is necessary at times, their journals showed they favor using guided notes with applications to real life still embedded in the notes over an open note format.

Choice

The next theme in student journals was choice, which supported the phenomenographical analysis. The students mentioned in the journals the choice board of the final project and their ability to be creative in their responses. This final project can be found in Appendix L. Amelia mentioned these activities in her journal:

> My group and I finalized the lyrics for our statistics song and started working on planning the video. I like this project because we are incorporating statistics into something that is really creative. Next, I worked with a partner to create some statistics memes. This was really fun because it combined something that we were exposed to all the time, such as memes, with stats.

Other groups mentioned how fun it was to make dice and test the data to see if they had made them fair. The final project gave them many choices to apply their statistical knowledge in a fun and creative way that engaged them.

Application to the Real World

The students' journals mentioned that the activities applied to the real world. Oppenheimer stated, "The activity we did on Friday (Skew The Script, 2022), even if it was controversial, shined some new light on the topic and how Statistics is able to be used." In his journal, Aiden shared similar sentiments: "The packets used real-world applications to math, making them interactive and interesting." This supported the phenomenographical analysis of the student interviews showing that real-world application was important for students to engage in the activities.

Summary of Findings from Student Journals

The thematic analysis of student journals showed support for the phenomenographical analysis. Similar themes involved student choice and students working in groups. The journals are not as robust as the interviews, as the students were not able to be probed further. I had to rely on the responses that they provided. A theme that came out of the student journals that was not as prevalent in the student interviews is that guided notes are preferable to open note formats. Students who must take notes to learn the material prefer guided notes with places to fill in short phrases or words rather than writing everything out freehand.

Findings for Student Disengagement

In addition to students discussing reasons for engagement, some reasons for disengagement also emerged in the analysis of student interviews and journals. These findings answer sub-question two of this study: Which learning experiences disengage learners and why? Twenty-five of the 278 quotations referenced disengagement in the student interviews. The three main codes referenced for disengagement were passive learning, lack of personal choice, and lack of confidence. Only one of these themes was present in the student journals, which was passive learning.

Passive Learning

Three participants mentioned that passive learning is disengaging to them, and one repeated it in the student journals, which makes up 13 of the referenced quotations in the student interviews and only one reference in the student journals. Oppenheimer references this when he said, “Perhaps one of the least favorites would have to be the pure notes. The activities where we just sat through and did notes on.” He said he understands why this kind of learning is important to the learning process, but when reflecting on his disengagement, he admitted that he was not

"mentally there." He admitted that those moments were non-conscious moments in class for him. He explained that he closed his eyes at times when he was listening, but at other times he was completely checked out. He liked guided notes to help him remain engaged in learning. Similarly, Amelia said,

> So, I think in general, the notes are effective, but it can be hard to stay engaged the entire time because there are a lot of them. I also think that we need a lot of them because you need repetition in the practice. So, maybe, I guess, the format of the notes and switching it up a bit more would help it to be more engaging.

Students felt better when they could be actively learning concepts together in a group activity than to be passively sitting and taking notes.

Lack of Personal Choice

Only three of the students and seven of the referenced quotes mentioned lack of personal choice as a deterrent to engagement. Some students did not like the use of predetermined data and predetermined activities. Fiona's quote demonstrated this,

> But the Beyonce lyrics activity was more like, we had the lyrics we had to choose from. If we had gotten to choose our own song to observe the average number of letters, I feel like that would have been more interesting.

Amelia said she was disappointed that the activity, where the students rolled three different types of dice to perform chi-square analysis, only led to one outcome. She wanted to see data as a graph and use more technology in the activity. Lack of choice was frustrating to her during that activity. Students stated that their engagement waned when the topic was something they were not interested in, like Beyonce's lyrics. When students were given activities that gave them pre-existing data and did not have a choice in the learning, they were less engaged in the topic.

Lack of Confidence

Three students mentioned a lack of confidence when disengaging from an activity or topic. Willa's quote demonstrates this idea, "So when I'm bad at something, I just don't like it. I call it gifted kid syndrome. As soon as you're not good at something, you just quit." Bella mentioned that she struggled with tests, which were always difficult for her to complete on her own without a group; the tests caused her to overthink her work and caused much anxiety. Oppenheimer also mentioned the idea of overthinking some questions on his quiz. Aiden described a class activity requiring them to memorize words using two different memory techniques. He said it was difficult to engage in this activity because "My brain isn't like for that kind of experiment to put it into a story… so that one was harder for me." Once the students had an activity that was difficult to overcome and not something they didn't value, it became very easy for them to disengage.

Summary of Findings for Student Disengagement

The themes for student disengagement were passive learning, a lack of confidence, and a lack of choice. Students recognize there are times when they must learn with notes and passive learning in class; that is the nature of learning something difficult. The activities helped them learn through class-driven data were not always engaging to them because the data was pre-conceived or was based on uninteresting concepts. Sometimes the activities seemed overwhelming or something they were not naturally good at, so they found themselves disengaged due to their lack of confidence in the activity or the material.

Summary

This chapter discusses the findings of this study on student engagement in the AP Statistics flipped classroom. This study aims to explore effective strategies, activities, and

technology tools that engage and disengage students in the classroom. The four categories of description that emerged from the phenomenographical analysis of students' interviews describe students' voices on engaging activities. These categories of description are activities that allow the students to be social, activities that activate students' cognitive thinking, activities that increase positive emotions, and student internal motivation. The outcome space was developed to show the relationship between these categories of description in a hierarchical manner. The findings suggest that collaborative and active learning activities that tie to real-world applications engage students. Student journals and interviews show that students were more engaged when they could apply their knowledge, create their data, receive instant feedback through technology, feel challenged by tasks, have choices, and enjoy them. Student internal motivation plays a role in their engagement. They were more apt to persevere through challenging tasks when they were engaged in the tasks. Students also needed to feel confident in their abilities before they could tackle challenging tasks. The findings also suggest that passive learning, lack of personal choice, and lack of confidence can contribute to student disengagement. These findings highlight the importance of active learning, context, technology, choice, and internal motivation in promoting student engagement in a flipped AP Statistics course.

Chapter 5: Discussion and Implications

Math engagement is a significant issue in schools today. Engagement declines as students advance through school (Attard, 2014; Hodgson et al., 2017). Most notably, engagement declines sharply as students enter high school (Gallup, 2017), and mathematics engagement decreases severely as students move from middle to high school (Attard, 2014; Collie et al., 2019). Thus, this study was conducted to study engagement in a flipped high school AP Statistics classroom. Engagement is widely accepted as a multi-dimensional construct that includes behavioral, affective, and cognitive dimensions (Fredricks et al., 2004). Recently, a fourth dimension of engagement has been considered due to the increasingly interactive nature of classrooms (Fredricks et al., 2016; Linnenbrink-Garcia et al., 2011). Studies on engagement in the math classroom have studied behavioral engagement (Hodgson et al., 2017) and the three dimensions of engagement in a math class (Cevikbas & Kaiser, 2021; Lo & Hew, 2020), but research on all four dimensions of engagement in a math classroom is lacking. In addition, most research on engagement has used either action research, quasi-experimental, quantitative, or mixed methods (Bond, 2020). Qualitative methods of research, including phenomenography, are lacking in high school-level mathematics engagement studies. Therefore, this research sought to answer the questions:

- How do AP Statistics students experience engagement in the flipped classroom?
    - Which learning experiences help to engage students and why?
    - Which learning experiences contribute to student disengagement and why?

These questions were analyzed through qualitative, phenomenographical study with six participants to understand the student's perspective of engagement.

This chapter will include a discussion of findings for engagement and disengagement from the phenomenographical analysis of student interviews and thematic analysis of student journals to answer the research questions posed. The limitations of the study conducted will be addressed. The implications and recommendations will also be discussed.

Discussion of Findings

This research was conducted to answer the overarching research question: How do AP Statistics students experience engagement in the flipped classroom? Student responses in the interviews and journals overtly reflected a preference for activities meeting three dimensions of engagement– social, cognitive, and affective engagement. The students also discussed disengaging activities in the student journals and interviews.

Activities that Engage Students

The first sub question of the research was: Which learning experiences help to engage students and why? The students described engaging activities in the interviews. The most prevalent theme in student interviews and journals was activities that implemented collaborative teams related to their social engagement. The flipped classroom research shows the collaborative nature of the classroom activities helps them to form strong relationship with their peers and teacher (Avery et al., 2018; Aycicek & Yelken, 2021; Cevikbas & Kaiser, 2021; Kostaris et al., 2017; Muir, 2018; Tapia et al., 2021; Unal & Unal, 2017). Engaging math classrooms have continuous interaction among students (Attard, 2014), and social engagement is activated when the teaching methods rely on students' social interactions (Fredricks et al., 2016; Linnenbrink-Garcia et al., 2011). Social engagement is also present when students are willing to form and maintain relationships when they are learning (Wang et al., 2016). The flipped classroom

provides the time for students to actively learn in collaborative learning groups by moving the direct instruction outside of the classroom.

Collaborative learning, where students can divide the workload, communicate ideas and solutions with peers, and synthesize learning with others' perspectives, is very effective when teaching statistics (Brown, 2008; Chance et al., 2007; Fredricks et al., 2018; Irvine, 2020a, 2020b; Shah et al., 2019). Students could move to independent problem-solving and knowledge after working through collaboration with their more capable peers (Vygotsky, 1978). Whether students worked asynchronously through technology or in the classroom, this study supports the idea that collaborative activities were considered engaging, which agrees with current research.

Cognitive engagement was the next theme that came through in the analysis of student interviews and journals. Cognitively engaged students are internally driven to exert effort to understand and overcome challenging tasks (Fredricks et al., 2004). Students mentioned the activities that allowed them to apply their knowledge to real-world activities were engaging. Authentic learning (Bond & Bedenlier, 2019) explicitly linked to students' lives outside the classroom (Attard, 2014) is more engaging to students. These activities give students a purpose to learning (Bond & Bedenlier, 2019). Connections help students understand the relevance and answer why they are studying the content (Attard, 2014), which engages them to work harder to find the solution or to search for real-world applications of their knowledge outside of class.

Students are cognitively engaged when they are actively learning. Moving direct instruction outside of the classroom provided time for students to have student-centered active learning experiences. The engaging activities students mentioned in the interviews allowed them to create something and work in their teams. This supports Dewey's (1938) belief that the teacher needs to move away from being the center of student learning and the importance of the

teacher's scaffolding of the lesson for students (Shvarts & Bakker, 2019) so they can work independently. Active learning cognitively engages students and helps them to internalize the learning. Cognitive engagement is the most common predictor of achievement in high school students (Maamin et al., 2022). Student-centered, active lessons in which students created their own data were engaging, fun, interesting to students, and cognitively engaged them in the flipped AP Statistics classroom.

The use of technology helped students to be able to cognitively engage with projects. Student interviews mentioned that technology did the hard part of the math calculations, which allowed them to focus on the interpretation of the data. With the help of technology, students can create detailed data displays quickly and do calculations without the need for complex mathematical formulas (Chance et al., 2007; Salim et al., 2018). Student interviews showed that students cognitively engaged with projects using technology to create graphs and calculate complex mathematical formulas.

The third category of description analyzed from student interviews was activities that increase students' positive emotions. This category directly relates to their affective engagement. Affective engagement relates to students' emotions and reactions to interactions in the classroom (Fredricks et al., 2004). When students have high affective engagement, they value their learning and believed it would be useful outside the classroom (Attard, 2012). Participants in this study had a greater affective engagement when activities were fun, so they did not feel like working. The students also preferred challenging tasks. Fredricks et al. (2018) found that more challenging and difficult tasks were more engaging for students. Surmountable challenges brought feelings of satisfaction and accomplishment to the participants. The framework for math engagement stated challenging tasks suitable for all students provide them with a level of success (Attard, 2014).

Students also enjoyed tasks that allowed them to use technology. The students appreciated dynamic displays of data and instant feedback so they could focus on data analysis. The framework for mathematical engagement states that tasks should have technology embedded in them to enhance understanding of concepts (Attard, 2014). When tasks gave the student a feeling of engagement through positive emotions, they preferred tasks that were relevant to the real world, applications of knowledge learned in the class, challenging tasks that were achievable, and technology use to give them instant feedback for the data they collected.

Student motivation was the final category of description resulting from the analysis of the student interviews. Motivation is related to engagement and occurs before engagement (Skilling et al., 2021). Students' interest and self-efficacy in their abilities are influences in the microsystem of student engagement (Bond, 2020; Bond & Bedenlier, 2019). Students' internal motivation helped them to persevere through difficult content and try multiple times to master their goals. Their perseverance and success gave them feelings of self-efficacy. Participants stated their knowledge of content before projects were assigned helped their confidence and was important to their engagement. Students also mentioned that being given choices helped with their internal motivation to engage in the task. The framework for mathematical engagement (Attard, 2014) states that students need to be given an element of choice to be engaged. Projects allowed them to make choices, leading to student engagement. Students' internal motivation is driven by choice and self-efficacy, which drives perseverance to overcome challenging tasks (see Figure 8).

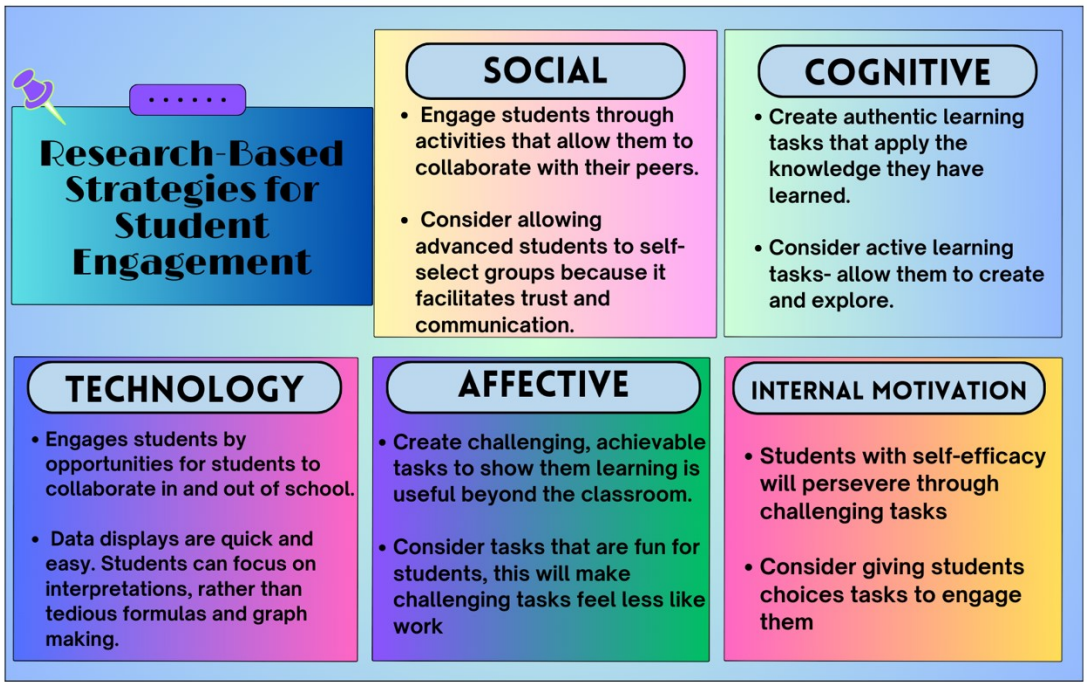
Activities that Lead to Student Disengagement

After an analysis of student interviews and student journals, themes of disengagement were found. Disengaging activities usually lack fun and excitement, provide no instant

gratification, and do not align with goals and values (Norton, 2017). Student interviews and journals showed that students had affective, behavioral, and cognitive disengagement during class. The three main themes of disengagement were caused by passive learning, lack of personal choice, and a lack of self-confidence.

Figure 8

Research-Based Strategies for Student Engagement



Passive learning was the most mentioned disengagement theme in student journals and interviews. Some of the classroom activities were done as a class together. Participants sometimes considered the activities to be open-note format packets even though activities started with collecting data. Some of the activities were taught with direct instruction due to the content being learned. Direct instruction is learning with purposeful learning goals, demonstration of concepts, checks for understanding, and closure (Hattie et al., 2017). While students know this type of learning is necessary, they are not always engaged with it. One participant admitted to

closing his eyes and checking out completely during just notes days when he was tired. He was a capable student and understood the material, but because he was not engaged, he easily gave in to how tired his heavily packed schedule with little sleep made him. Passive learning, like when students are taking open-format notes, is behaviorally and affectively disengaging for students.

When participants found an activity or quiz overwhelming, they were prone to be disengaged. These are tasks where students overthink what is happening or have a sense of anxiety when they are completing the tasks. Students that lack self-efficacy have difficulty remaining engaged when they were frustrated with the material (Brown, 2008). Disengaged students that are overwhelmed will often stop participating in activities during class leading to behavioral, cognitive, and affective disengagement.

The final factor which caused student disengagement was a lack of choice. The framework for mathematical engagement stated that students need to be provided with a choice element for them to be engaged (Attard, 2014). The participants mentioned activities where the content was predetermined sometimes made them disinterested. Other times, students were disengaged because they did not actively participate in creating the data for the activity. The students wanted to be given a choice in the content for the activities that they did in class, or they considered the activity to be affectively disengaging.

Limitations of the Study

The most significant limitation of this study was the class size. The class started with only 17 students and ended the semester with 16 students. Research stated that the optimal number for a phenomenographic study was 10-30 (Trem, 2017). A demographic difference in my class helped provide maximal sampling in my research. However, I was limited by the

number of students willing to participate in the study, which was further complicated by the number of students to choose from.

The second limitation was that I was the sole teacher-researcher of students in my class. As the sole researcher, the amount of data I could process was more limited than a team. A sole researcher can have valuable insights, but the results may not be as developed as a team's (Akerlind, 2005a). To help with this, I have used a fellow researcher familiar with the transcripts to play devil's advocate and discussed my results with my dissertation chair.

Implications and Recommendations from This Study

Implications and Recommendations for Research

This study shows important implications for research, practice, and teacher education. First, this study shows a link to all four dimensions of engagement within a flipped AP Statistics classroom that uses class time for active, collaborative learning. In fact, the students considered social engagement to be very important in the class and it was coded most often in student transcripts. The behavioral engagement was not coded in the student transcripts, but their behavioral engagement was present in their descriptions of their work on the projects and activities in class and in their desire to persevere in learning the content. In this study, it was evident that AP Statistics high school students in a flipped classroom model experienced engagement when they were working on authentic projects that applied their knowledge (cognitive engagement) in collaborative teams (social engagement), which helped students to enjoy the activity (affective engagement), and they chose to persevere through any challenges (internal motivation) to complete the tasks. Therefore, this study supports that social engagement should be considered a dimension of engagement in addition to the traditional dimensions of behavioral, affective, and cognitive engagement (Fredricks et al., 2004).

Further study is needed on studying the fourth dimension of engagement in all subjects as social engagement is an emerging construct of engagement and perhaps the most important dimension of engagement for high school students. In addition, it would be beneficial to study all four dimensions of engagement in other subjects. Future research would also benefit from a larger sample size. The sample size of only six students was small for a phenomenographical study and may not have provided optimal variation because all the students were advanced in an AP Statistics course. All four dimensions of engagement should be studied with students at different grades and levels in high school.

The students did not mention the videos or pre-class work in their interviews. Previous research states both positive and negative aspects of the flipped videos for students. On the positive side, students appreciate the self-paced nature (Bhagat et al., 2016; Cevikbas & Argum, 2017; Conner, 2021; Graziano & Hall, 2017; Tapia et al., 2021; Yang et al., 2021) and the ability to review the material (Unal & Unal, 2017). On the other hand, students can be resistant to the change from the traditional classroom (Cevikbas & Kaiser, 2021; Lo et al., 2017) or a perception of an increased workload (Lag & Saele, 2019). Students can also resist videos because they have problems with time management (Florence & Kolski, 2021) or are not motivated to adjust their habits (Satparam & Apps, 2021). The fact that students did not mention the videos as engaging or disengaging could be an indication that they had adjusted their habits and accepted the videos as a task of the classroom. It is possible that the students did not mention the videos because the questions asked them about interesting/uninteresting and enjoyable/less enjoyable activities, and they did not consider video watching as an activity.

The videos provided in this study were short and introductory ones to introduce the lesson, the learning expectations, and the formulas that would be used in the content the

following day. Future research should focus on how flipped classroom videos can engage students more in this day of reels and TikTok videos. It is possible that six to ten-minute videos are too long to capture students' attention or engage them in this post-Covid time frame.

Implication and Recommendations for Practice

Some recent research has stated high school students choose self-selected groups for reasons that have nothing to do with solving math problems (Liljedahl, 2021). These students form groups that fall into the patterns that already exist within their social dynamics and students may never rise to be leaders within their group (Liljedahl, 2021). Hilton and Phillips (2010) performed a mixed study on group formation and determined that students had more positive experiences in self-selected teams when looking at group inputs, group processes, and group outcomes. They found that self-selected groups reported that students' experiences feelings of ease, comfort, and trust. These positive feelings led to an ease of starting up projects and increase participation; however, they did not find statistically different achievement in self-selected groups over teacher-selected groups (Hilton & Phillips, 2010). In their recommendations, they did not suggest teachers to use self-selected groups for every project as they determined that students learn communication skills and how to work through and overcome organizational challenges, as they build teaming skills in teacher-selected groups (Hilton & Phillips, 2010). My research shows that students felt more comfortable with teams comprised of people that they knew. A couple of students overtly state that forcing them into teams would be disengaging. In other words, in an advanced class, self-selected teams are beneficial to the group. While the students are friends, their goal is to be successful and understand the content, so it helps to lessen the drive to be distracted from the work. This finding supports the research results of Hilton and

Phillips (2010). However, although Hilton and Phillips (2010) did not recommend teams, my research shows that it may be disengaging for students if they are not in self-selected teams.

In practice, statistics teachers should consider activities where students collect the data that they use in class, either individually or as a class. Students recognize the data point that they have created and are able to follow their data through the activity. This is supported by research from Cobb (1992) when he mentions that statistics should be taught as a laboratory science course and students should have demonstrations with class-generated data. Students are more engaged and can understand data that they have created when learning new concepts in statistics courses.

When students must take notes, a guided note format is more engaging than an open-note format. Students used open notes often during the year and when the students switched to guided notes, participants stated that they were more organized, easier to look back on, and that they were more engaged with filling out the guided notes. The one student that admitted to being disengaged during notetaking stated that guided notes would help him to stay on task as it was easier to complete than writing large amounts of notes. Another student stated that open-note formats were difficult to complete while she was learning a concept. Guided notes during direct instruction can help students to stay engaged with the content.

Students should be given an opportunity to work in collaborative teams and given autonomy to choose how they would like to demonstrate their learning through projects that relate to the real world. The activities considered engaging were often scaffolded, challenging tasks that gave them choices. Students felt confident in their teams and knowledge, so they rarely asked for help. I truly became the guide on the side and only had to answer a few questions when they were really stuck or wanted clarification of expectations. The self-efficacy students had in

their knowledge, along with their trust in their teams, made their need for a teacher almost non-existent.

Implication and Recommendations for Teacher Education

Teacher education should include the discussion of all four dimensions of engagement and methods that students deem as engaging. The most prevalent of which is social engagement and having students work in collaborative teams. Collaborative teams allow students to synthesize their knowledge and prepare them for the workforce. While self-selected teams may not be successful in all math classes, advanced students, who are already driven to be successful, benefit from the trust and comradery that occurs when they are working with their friends on difficult or complex tasks. Teacher educators should help pre-service and in-service teachers understand how to choose strategies for engagement based on their student populations.

Teacher education should stress the importance of authentic, real-world learning activities for students in the classroom. Luo et al. (2017) presented a framework of characteristics to describe authentic learning opportunities to train pre-service teachers about online teaching. The framework states that authentic tasks are real-world, collaborative, unstructured, interdisciplinary tasks, that are to be completed over an extended time frame (Luo et al., 2017). These tasks require the participants to use many resources and viewpoints to analyze the task, are connected to assessment, and provide for reflection (Luo et al., 2017). The outcomes of authentic tasks stand on their own and do not directly lead to another task (Luo et al., 2017). These tasks have the possibility of differing solutions (Luo et al., 2017). Luo et al. (2017) suggest that pre-service teachers benefit from learning through authentic learning activities to implement a face-to-face or online course for K-12 students. Students in this study were engaged with activities that were authentic, challenging, real-word activities that related to

their learning. More teacher education and professional development activities should be presented to assist teachers in creating such opportunities for students in the classroom.

Math teachers sometimes have difficulties using technology in the classroom. A recent study showed that math teachers still struggle with the thought that technology requires a lot of time out of their teaching and that constructivist teaching methods are less controllable (Thurm & Barzel, 2022). That study also found math teachers still believed technology used posed the risk of losing historically important mastery of working mathematics by hand (Thurm & Barzel, 2022). It is essential for teachers to understand that technology is beneficial when teaching students, particularly in statistics. Math teachers should use technology within the classroom for students to do simulations and for them to be able to understand and grasp math concepts without the need for complex math calculations (Chance et al., 2007; Salim et al., 2018). In turn, teacher educators should prepare both pre-service and in-service math teachers to integrate technology effectively to promote student engagement.

Research has shown that technology increases engagement in the classroom (Attard & Holmes, 2020a, 2020b; Biber et al., 2022; Funcheon, 2020; Salim et al., 2018), and in the math classroom (Attard, 2021; Irvine, 2020a, 2020b; Salim et al., 2018). This study has shown that students are engaged when technology allows them to work on tasks collaboratively with one another both synchronously and asynchronously, allowed them to focus on the interpretation of data rather than creating data displays or completing complicated math formulas, and created displays quickly with design elements that made the outcome pleasing. Teacher education programs must make pre-service educators aware of the benefits of technology and the ever-changing landscape of technology. Teacher education programs should also stress the importance of forming professional learning networks to help them to understand the latest technology

available and classroom implementation of the technology. Educators must be life-long learners to keep up with the changing technology during their careers. Many math teachers would like to integrate technology more effectively but lack the knowledge to do it and do not have the time to research all the emerging technologies; therefore, they stick to the traditional ways of teaching that make them comfortable. Schools and districts would benefit by providing professional development opportunities for in-service teachers to complete student tasks using technology further to develop their understanding and need for technology integration.

Conclusion

This qualitative, phenomenographical study sought to explore AP Statistics students' varied lived experiences of behavioral, affective, cognitive, and social engagement in the AP Statistics course using a flipped classroom approach; to understand and give students a voice to understand the learning experiences that engage and disengage them in the classroom; and contribute to finding effective strategies, activities, technology tools, or design features for a high school math classroom that sustain student engagement. This research found that when students are engaged, they experience all four dimensions- social, affective, cognitive, and behavioral engagement. Students' interviews and journals showed that social engagement is a very important dimension of engagement to them. Students engaged socially when activities were done in collaborative, self-selected teams. The students trusted their friends and believed that they were more successful when they worked together to synthesize their learning. If the students were not familiar with a topic, their teammates were able to play the part of a more knowledgeable other and move them through the zone of proximal development (Vygotsky, 1978) until they could independently complete the tasks on their own. Technology was able to help them to work collaboratively on projects easily when they were not in class together.

Students were cognitively engaged when they applied their knowledge in authentic tasks when they were actively learning and given the opportunity to create the data they used to learn. Technology provided them with instant feedback so they could focus on the concepts rather than the daunting math formulas. Students engaged affectively with tasks that were challenging and enjoyable, and when technology gave them easy and dynamic results. Students were driven to engagement by their internal motivation to persevere through challenging tasks and a desire to do well. Students were also internally motivated when they were given a choice, and they felt self-efficacy with the topic they were demonstrating. Students were disengaged when tasks were passive, did not give them choices, and when they lacked self-efficacy. The implications advocate for the use of active, collaborative learning techniques to engage students in the flipped AP Statistics classroom. More importantly, both pre-service and in-service teachers should learn about the strategies and technology tools that promote student engagement in their classrooms.

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Appendix A

Script to Recruit Students

I am conducting a study to increase my understanding of engagement in the AP Statistics flipped classroom as experienced by students in my AP Statistics class. As a student in the class, you are in an ideal position to inform my study.

The interview will be no longer than an hour, and during this time, I would like to capture your thoughts on activities we have done in the class. Your responses to the questions will be used to inform my study, but you will never be named in the study. You are not required or obligated to be a part of this study for this class. The interviews will not occur until your grade is finalized for the course.

There is no compensation for participating in this study, but your participation will be a valuable addition to my research and findings could lead to a greater understanding of teaching and reaching students in the AP Statistics classroom.

If you are willing to participate, please take parental consent forms to get permission from your parents to participate in the study and student assent forms. When they are returned, we can set up a time and date for your interview which can be done in person or through a Zoom call.

Appendix B

Parent Consent Form

Parental Permission

Study Title: AP Statistics Students' Conceptions of Engagement and Technology in a Flipped Classroom: A Phenomenographical Study

Researchers Contact Information

Kimberly A Gile	470-980-6840	kgile@students.kennesaw.edu
Yi Jin (dissertation chair)	470-578-3814	yjin8@kennesaw.edu

My name is Kimberly Gile. I am your child's AP Statistics teacher and a doctoral research candidate at Kennesaw State University. I am inviting your child to take part in a research study. This form will tell you about the study to help you decide whether or not you want your child to participate.

Why is this study being done?

The purpose of the study is to help learn about engagement in a flipped classroom for AP Statistics students.

Your child is being asked to participate because he/she is in a flipped AP Statistics class this semester.

What am I being asked to do?

If you decide for your child to be in the study, I will ask your child to participate in one interview that lasts approximately 60 minutes each to ask about engagement in the class activities. This is completely voluntary.

The interview will be conducted outside of classroom hours at the end of the school year. They can be done face-to-face with me in my classroom, or they can be done as a Zoom interview. I will conduct all interviews with your student after their grades are submitted and finalized.

The students have completed journal entries for the course. The journal entries will be collected as a part of normal class reflection. The journal entries will be used as data for the research.

Your child's identity will never be mentioned in the study or in any other way. The results of the study reflect all interviews as a whole, so your child may not recognize their answers specifically reflected in the published study. If I use a quote from your child, they will be given a pseudonym.

Please understand as mandated reporters, Mrs. Gile has a legal obligation to make a report and notify appropriate adults if your child's safety is in danger regardless of whether it relates to the research.

What are the benefits to me for taking part in the study?

There are no expected benefits to your child, but the research may help contribute to a larger body of research that helps teachers understand strategies that help students engage in a flipped classroom.

Are there any risks to me if I am in this study?
The potential risks of taking part in this study are:
There are no known risks to this study.
Interview questions will ask students to describe their experiences with activities that we have done in the classroom. If at any point they are uncomfortable, they may ask to be removed from the study, and all the data I have collected will be destroyed.

Will my information be kept private?
Your child will be given a pseudonym within the research. Identifying information will not be collected on your child. If your child participates, they will be assigned a number known only to Mrs. Gile and the interviewer.

On Zoom calls, your child will not use their name on the recorded portion of the interviews. Your child may also choose to leave the camera off or use an avatar so that their voice is the only recorded thing, if preferred. IP addresses will not be collected. All data kept on a computer will be on a password-protected computer and will not have their name or any identifying information with the data.

Compensation
Your child will not receive money or any other compensation for participating in this study.

What are my rights as a research study volunteer?
Your child's participation in this research study is completely voluntary. They do not have to be a part of this study if you do not want them to or they do not want to. There will be no penalty to your child chooses not to take part and no one will be upset or angry at them. Your child may choose not to answer any questions they don't want to answer, and they can change their mind and not be in the study at any time.

Who can I talk to if I have questions?

If you have questions at any time, you can ask the researchers and your child has been encouraged to also talk to you. We will give you a copy of this form to keep. If you want to ask us questions about the study, call or email myself or my dissertation chair.
If you have any questions or concerns regarding your child's rights as a research participant in this study, you may contact the Institutional Review Board (IRB) Office at irb@kennesaw.edu.

Research Subject's Consent to Participate in Research:

To voluntarily allow your child to take part in this study, you must sign on the line below. Your signature below indicates that you have read or had read to you this entire Parental Permission Form and have had all your questions answered.

Your Child's Name:

Your Signature: Date

Your Printed Name:

Signature of Researcher: Date

Printed Name of Researcher:

Please sign both copies, keep one and return one to the researcher.

Appendix C

Student Assent Form

Research Study Assent Form

Name of Minor: _____

Parental Permission on File: ¨ Yes ¨ No**

***(If "No," do not proceed with assent or research procedures.)*

Study Title: AP Statistics Students' Conceptions of Engagement and Technology in a Flipped Classroom: A Phenomenographical Study

Researchers Contact Information

Kimberly A Gile	470-980-6840	kgile@students.kennesaw.edu
Yi Jin (dissertation chair)	470-578-3814	yjin8@kennesaw.edu

My name is Kimberly Gile, and I am from Kennesaw State University. I am inviting you to take part in a research study. Your parent(s) know we are talking with you about the study, but it is up to you to decide if you want to be in the study. This form will tell you about the study to help you decide whether or not you want to take part in it.

Why is this study being done?

The purpose of the study is to help us learn about engagement in a flipped classroom for AP Statistics students. You are being asked to participate because you are a flipped AP Statistics class member this semester.

What am I being asked to do?

If you decide to be in the study, we will ask you to participate in one interview lasting approximately 60 minutes about your experiences with class activities. This is completely voluntary. I will conduct all interviews at the end of May, beginning of June after your grade is finalized.

You will be able to choose to come in person or to participate in a Zoom call. You will be given a pseudonym for any recorded interview questions. No questions are required to be answered, and you may ask to discontinue being in the study at any time for any reason without anyone getting upset. No recording will be done without your permission.

I will also use your journal entries collected in class with your permission.

Your identity will never be mentioned in the study. The study results reflect all interviews as a whole, so you may not recognize your answers specifically reflected in the published study. You will be given a pseudonym if you are quoted.

Please understand as a mandated reporter, I have a legal obligation to make a report and notify appropriate adults if your safety is in danger regardless of whether it relates to the research.

What are the benefits to me for taking part in the study?

There are no expected benefits to you, but the research may help contribute to a larger body of research that helps teachers understand strategies that help students engage in a flipped classroom.

Are there any risks to me if I am in this study?
The potential risks of taking part in this study are:
There are no known risks or anticipated discomfort to this study.

Will my information be kept private?
The results of your participation will be kept anonymous. You will be given a pseudonym within the research. Identifying information will not be collected on you. If you participate, you will be assigned a pseudonym known only by myself.

On Zoom calls, you will not use your name on the recorded portion of the interviews. You may also choose to leave the camera off or use an avatar so that your voice is the only thing that is recorded, if you prefer. IP addresses will not be collected.

Compensation
You will not receive money or any other form of compensation for taking part in this study.

What are my rights as a research study volunteer?
Your participation in this research study is completely voluntary. You do not have to be a part of this study if you don't want to. There will be no penalty to you if you choose not to take part and no one will be upset or angry at you. You may choose not to answer any questions you don't want to answer, and you can change your mind and not be in the study at any time.

Who can I talk to if I have questions?

If you have questions at any time, you can ask the researchers and you can talk to your parent about the study. We will give you a copy of this form to keep. If you want to ask us questions about the study, call or email

If you have questions about your rights in the study, or you are unhappy about something that happens to you in the study, you can contact the Kennesaw State University IRB Office at irb@kennesaw.edu.

Statement of Consent

If you want to participate in this research, please sign below. By signing, you are agreeing to participate in this research.

_____	_____
Signature of Participant	Date
_____	_____
Signature of Researcher Obtaining Consent	Date

Appendix D

Course Timeline and Activities

Date	Activities
1/3	Can Joy Smell Parkinson's Intro to Stats Watch video on Sampling
1/4- 1/5	Lesson 4.1: Does Beyonce Write Her Own Lyrics? Lesson 4.2: How Much Do Fans Love Justin Timberlake? Types of Samples Watch video on Experimental Design
1/6- 1/9	Lesson 4.1 Day 3: What Is Wrong with These Surveys? Bias Lesson 4.2 Day 1: Does SAT Prep Improve Scores? Lesson 4.2 Day 2: Would You Fall for That? Lesson 4.2 Day 3: Does the Type of SAT Prep Matter? Experimental Design Watch video on Categorical Data
1/10	Group Quiz
1/12- 1/17	Lesson 1.1: How Are Your Favorite Classes Related? Mosaic Plots: What Will Be the Mascot? Categorical Data Watch video on Quantitative Data
1/11- 1/13	Review for Test Test over Unit 3
1/18- 1/19	Lesson 1.3 Part 2: Where Do I Stand? Boxplots & 5-Number Summary Day 4: Lesson 1.2: How Many Pairs of Shoes Do You Own? One-Variable Graphs Day 6: Lesson 1.3 Part 1: How Many Colleges Are You Applying to? One-Variable Stats Watch video on percentiles and z-scores
1/20	Lesson 2.1: How Did I Do? Z-Scores Ok7w5Lesson 2.1: Where Do I Stand? Part 2 Percentiles and Cumulative Frequency Graphs Watch video on Density Curves and Normal Distribution

1/23-1/24	Day 13: Lesson 2.2: Exploring Density Curves Density Curves + Empirical Rule Day 14: Lesson 2.2: Will Marty Make It Back to the Future? Normal Distribution Day 15: Lesson 2.2: Do We Have Normal Test Scores? Normal Probability Plots Watch video on Simulations
1/25-1/26	Gummy Bear Experiment
1/27	Test Unit 1
1/30-1/31	Lesson 5.1 Day 1: How Good is Mrs. Gallas at Free Throws? Intro to Probability Lesson 5.1: Are Soda Contests True? Simulations Watch video on Probability Rules
2/1-2/2	Lesson 5.1: Who Will Win the Last Banana? Probability Rules Lesson 5.2 Day 2: Taco Tongue or Evil Eyebrow Day 1 Probability Rules Lesson 5.3 Day 1: Taco Tongue or Evil Eyebrow Day 2 Conditional Probability & Independence Lesson 5.3 Day 2: Can You Get a Pair of Aces or a Pair of Kings? Tree Diagrams Watch video on Probability Distributions
2/3-2/6	Lesson 6.1 How Many Children Are In Your Family? Intro to Probability Distributions Lesson 6.1 How Much Do You Get Paid? Probability Distributions Lesson 6.2 Time for a Raise Lesson 6.2 What Will You Make Next Year? Combining and Transforming Random Variables Watch video on Sampling Distributions for Proportions
2/7	Group Quiz
2/8-2/9 and 2/20	Lesson 7.1: What Was the Average for the Chapter 6 Test? Lesson 7.1:What Was the Average for the Chapter 6 Test? Intro to Sampling Distributions Lesson 7.2: What Proportion of Reese's Pieces Are Orange? Sampling Distribution for One Proportion Lesson 7.2: Do Skittles and M&Ms Have Different Proportions of Orange Candies?

	Sampling Distribution for a Difference in 2 Proportions Watch video on Sampling Distributions for Means
2/10	Unit 4 Test
2/21- 2/22	Present Project on Bias to Students Lesson 7.3: What Is My Height? Lesson 7.3: Who Has Better ACT Scores? Sampling Distribution for One Mean Lesson 7.3: ACT Scores: Which School is Better? Sampling Distribution for a Difference in 2 Means Watch video on One Proportion Confidence Intervals
2/23	Group Quiz Sampling Distributions Proposal for Project on Bias Due
2/24- 2/27	Unit 6.1: Guess the Mystery Proportion Unit 6.1: Interpreting the Confidence Level Intro to Confidence Levels Unit 6.1 Which way will the Hershey Kiss Land? One-Proportion Z-Interval Unit 6.1: What proportion of Earth is covered by water? 4-Step Process Watch video on One Proportion Significance Tests
2/28- 3/1	Unit 6.2: Is Mrs. Gallas a Good Free Throw Shooter? Unit 6.2: Is This Gender Discrimination? Intro to Significance Tests Unit 6.2: Are You Sure Mrs. Gallas Isn't a Good Free Throw Shooter? One-Proportion Z-Test Watch video on Powers and Errors
3/2- 3/3	Unit 6.2: Should Rockford Switch to Bottled Water? Power of a Test Will Mrs. Gallas Prove Herself? Type I and Type II Errors Watch video on Two Proportion Inference
3/6- 3/8	Unit 6.1; Which grade is more likely to go to prom? Two-Proportion Z-Interval Unit 6.2: Is Yawning Contagious? Two-Proportion Z-Test
3/9	Group Quiz
3/10	Project Work Day Review

3/13- 3/16	Unit 6 Test Project Due Watch video on One Sample Mean Inference
3/20- 3/21	Unit 7.1: How much does an Oreo weigh? One-Sample T-Interval Unit 7.2: Are You Getting Enough Sleep? One-Sample T-Test Watch video on Two Sample T Inference
3/22- 3/23	Unit 7.1: Which Cookie Has the Most Chocolate Chips? Unit 7.2: Is One Form of the AP Exam Harder? Unit 7.3: Does Labeling Menus Reduce Calories? Two-Sample T-Procedures for a Difference in Means Watch video on Matched Pair T Inference
3/24- 3/27	Unit 7.1: Does Memory Training Help? Unit 7.2: Does Memory Training Help? Part 2 Inference for Paired Data Watch video on Chi-Square Inference
3/28	Group Quiz
3/29- 3/31	Are They Fair? Crooked, Round, and Car Dice Chi-Square GOF Test **Student Journals Collected**
3/30	Test Unit 7
4/9- 4/10	Unit 8: Does Gummy Bear Brand Matter? Chi-Square Test of Homogeneity Unit 8: Are Taco Tongue and Evil Eyebrow Independent? Chi-Square Test of Independence **Student Journals Collected**
4/11	Test on Unit 8
4/12- 4/20	Skew The Script Lessons on Linear Regression **Student Journals Collected**
4/21- 4/24	Review Unit 2 & Unit 9 Test Combined
4/25	Lesson 6.3: Is It Smart to Foul at the End of the Game? Binomial Distribution Lesson 6.3 Pop Quiz! Binomial Distribution

4/26	Lesson 6.3: How Many Bottle Flips to Go Viral? Geometric Distribution Lesson 6.3: Where Are All the Green Skittles? 10% & Large Counts Conditions
4/27	AP Exam Review Day
4/28	Group Quiz on Binomial and Geometric Distributions **Student Journals Collected**
5/1-5/3	Review for AP Exam
5/5-5/15	Students are introduced, collaborate on, and work on final project requirements. **Student Journals Collected**
5/16-5/17	Students present final projects
5/18-5/19	Senior Finals
5/22-5/26	**Interviews were conducted at this time**

Appendix E

Timeline of Study

	2022		2023									
	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUNE	JULY	AUG	SEPT	OCT
Months	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**
Comps												
Revision												
Permission from School												
Dissertation Proposal												
Writing IRB												
Dissertation Proposal Defense												
Revise Proposal if Needed												
IRB												
IRM Approval												
Final Approval from County												
Collect Data												
Analyze Data												
Write Ch 4 and Ch 5												
Dissertation Submitted to Committee												
Proposal Defense												
Revisions												
Petition to Graduate												
KEY												
planning												
writing												
fieldwork and analysis												
due												
Notes:												
Reading and writing happens throughout												
Meet with advisor throughout for advice												

Appendix F

Student Reflective Journals

Please describe the activities you have done this week in class and your experiences with the activities. Please describe an activity that you enjoyed and an activity that you may not have enjoyed this week. Please include how you felt about the activity and how the activity was or was not associated with learning.

Appendix G

Student Interview Protocol

Date:_____

Interview #_____

Hello, and thank you for taking the time to participate. The data from this interview will be used to inform my dissertation study of your experiences in the flipped classroom.

I want to be sure that I capture all your responses and can accurately review our conversation; I would like your permission to record this interview. If at any point you want to stop the interview and discontinue the use of the recording device, please let me know, and I will stop. You may terminate your participation in this study without any consequences. I will keep your responses confidential; if any responses are quoted, a pseudonym will be used to protect your anonymity.

I will ask you some questions over the next 60 minutes to understand your unique experiences related to some activities that you participated in for class. I am providing you with a list of our class activities to help you remember them. I want to understand your experiences and what you think. You are the expert here. There are no right answers or perspectives.

Do you have any questions before we begin?

Do I have your permission to begin the interview and start recording?

(Start recording if the answer is yes).

Thank you for your permission to record this interview.

Q1. In this class, we have done many activities. I want you to think back to the activity that was the most interesting to you. Please describe the activity for me.

Q2. Now, I would like you to think about an activity that you think was less interesting. You may look at the list for time to refresh your memory. When you are ready, please describe the activity to me.

Q3. We have now discussed two activities, one interesting and one less interesting. Please describe what was different between them. Why was one more interesting than the other?

I have been asking you to compare activities that are more or less interesting. Let’s focus for a moment on something a bit different- what activities do you actually like to do in class and what do you actively dislike doing. Let’s call them more enjoyable and less enjoyable.

Q4. First of all, I want you to think back to the most enjoyable activity for you, one that you really liked doing. Please describe that activity for me.

Q5. Now, I want you to think back to the less enjoyable activity; maybe you really disliked doing it. When you are ready, please describe the activity for me.

Q6. What was the activity less enjoyable compared to the one that you really liked to do in class?

I started the interview by asking you about interesting and less interesting activities and their differences. Then I asked about activities that you liked a lot and liked less and their differences. Now, I would like you to reflect on the distinction between an interesting activity and an activity you liked. As you think about these differences, please determine which type of activity typically leads to more learning or understanding.

Q7. Early in the interview, we discussed an activity that you thought was interesting to do and, later, one that you thought was enjoyable- that you really liked to do. Please describe what was different between the enjoyable and interesting activities.

Q8. Please describe any aspects that were similar between the enjoyable and interesting activities.

Q9. Please reflect on whether interest or enjoyment is more important for associating an activity with learning.

Q10. Is there any question you would like to go back to and reflect on more? Is there anything that you would like to add?

Thank you for your time and thoughtfulness in your responses.

I will transcribe this interview word for word. My research will examine your transcript along with all the other transcripts. You will not be personally identified in my research outcomes or published documents. If you want to check to be sure that I have accurately captured your words, you can indicate that on the form I give you. I can send you the interview transcript in about a week if you request it. Thank you so much for your time and for volunteering for my study, I will gladly send you a copy of the results if you want to see them as I complete my study.

Possible Prompts as suggested by Bowden (J. Bowden, personal conversation, Mar 4, 2023). I used the engagement and disengagement indicators as a framework to help to build the prompts for students.
Start probes with, “You said X” then add probe.

Engagement Indicator	**Student discussion**	**Probes to link the two**
Working as a team	Any description by the student using ‘we’ (or anything about pair or team together).	How did you come to that decision? Why did you decide that? How did that work out?

		How did you feel about that?
Self-efficacy/self-confidence in content	Any description of self confidence or great understanding of the material	How did that feel? How did this activity help you to feel confident?
Use of technology assisted learning	Any discussion of student use of simulations of calculator	Please describe your use of the technology more. How did the calculators/simulations help you to come to that conclusion?
Applying knowledge to other situations	Any discussion about how that activity made them realize something else outside of Stats class	How do you compare those two concepts? How did that make you feel?
Positive interactions with peers/teacher	Any discussion of interaction with peers/teacher	How did these conversations affect you in the activity?
Staying on task/persistence	Any discussion that talks about persistence to solve the problem	How did the activity contribute to your staying on task or persisting?

Disengagement Indicator	**Student discussion**	**Probes to link the two**
Boredom	Any description by the student boring or dull	What about this activity was (boring, dull, or X)?
Apathetic	Any description of not caring or wasn't worth their time	How did this affect what you did in class?
Avoidance	Any discussion about how they didn't participate in the activity	Please expand on how this activity led to you not participating.
Working alone during group work	Any discussion of them feeling like they did everything on their own or they worked alone	Why did you work alone? How did this make you feel?

Appendix H

Codebook

Categories of Description	Code	Definition	Example
Activates students' cognitive thinking	Application of knowledge	The students apply their knowledge in different ways through activities in class.	"We got to apply the knowledge of the stuff we've learned in class, like how do you sample our data, how to perform the interview, and what we could improve on after the fact." "I think it makes it more fun because it's kind of different than what we normally do at school in terms of like packets and paperwork and everything. When we do get a chance to like actually see and work with what we're talking about makes it more engaging."
	Application connected to the real world	The students see the application is connected to read world and as useful beyond the classroom.	"A lot of kids say like, when will we actually use this and like don't tell math teacher or whatever (referring to other math classes) this is a scenario where you would use it, or if you go into the field, like you could use it." "That was really cool because it kind of let us take stats outside the classroom and so it was more real life and I feel like we're doing was almost like an actual experiment."

Activates students' cognitive thinking	Active learning	The students engage in learning through participation and hands on activities.	"Physical like doing something that require physical activity." "It was tangible like we could actually like see it happen in front of us rather than seeing it on paper." "I remember using a lot of duct tape and like measuring it out and using books to stack it."
	Instant feedback through technology	The students interact with technology through instant feedback to understand the material better.	"Anytime you click on it, and it tells you this is correct. It gives the explanation. Yeah, it also tells you why your answer is wrong or right. Like go to the wrong one, it tells you this is wrong because (reason). I think that is helpful because sometimes whenever I'm answering questions, my issue isn't why the answer is right, it is why my answer is wrong."
	Opportunities to Create New Data	The students collected data to create data points that provided context for in-class activities and projects.	"It wasn't just data that we found online that we just kind of had to believe. It was data we got ourselves and saw that this is actually statistically significant for real."
Allows students to be social	More knowledgeable other	When working in groups, students always knew that if they didn't know something they could rely on another classmate to be able to explain the concept.	"So, like if I was confused on something, one of my partners would know how to do it, or if they were confused about something, I might know how to do it."

Allows students to be social	Comfort in a self-selected team	The students selected their friends to form teams, which helped them to feel comfortable.	"Well, since they're my friends, we were able to communicate better. So everybody like has a role within it. So we kind of expedited that went by pretty quickly, rather than just me sitting there, like independently just working on it." "I just like to be working in groups and I like that we pick our own groups."
	Trust in the Group	The students trusted the members of their group to ask questions and perform well on difficult challenges.	"Well I feel like I knew that we're all like understanding the material. So I felt confident in what they were going to put. And I just felt confident that if we weren't together like we would come up with something good because if we all thought it then it was I feel like there was a better chance that it would be right than if just one of us thought it." "Sometimes people just need help. But when their helping you their kinda like, egotistical about it and like kind of rude and like oh, how do you not know that, you're stupid. Nobody was like that in my group. It was very like this is how you do it."

Allows students to be social	Collaborations through technology	The activity was able to be completed by students together while they were at separate locations or it could be completed at different times through technology.	"So there were times where my partner and I were together and we both had to work on the project. That was something we could actually do through Google slides because it's updating under the person side, versus we'd done something on paper, if we don't both have a copy or it's not constantly updating to the other person can't see it. So for us, specifically, Google Slides was a big help because especially on things like whatever we did the work knowing that we were going to go home and work on the project."
Increases students' positive emotions	Tasks that student enjoyed	The students think that the activities make them feel positive emotions.	"I like doing things I am good at because it makes me feel good about myself."
	Tasks that challenge students	The students felt accomplished when conquering challenging tasks.	"It felt great because once we were done with finding all the statistics, we're essentially done with the project. So just being able to complete something that we had found difficult, it gave us a sense of accomplishment."
	Tasks that technology made easy	The students felt like the technology application was easy to use and helpful.	"Using Stapplet to do the data. That was so much easier than like drawing it by hand or honestly even using our calculator because you can't take a screenshot with a calculator."

Student internal motivation	Self-efficacy	Students felt confident in their knowledge and the ability to apply it.	"It made me feel much more prepared if we took the project knowing that I kind of already had been practicing the content." "If you know what you are doing, then it keeps you engaged."
	Perseverance	Students persisted in a task to be successful when the task was challenging.	"Through constantly failing, we realized this is actually something that we need to figure out how to do properly because we weren't maybe not necessarily putting in the most effort at first when it came because we thought it'd be easy." "If you are interested in doing something, then you'd be more likely to take time out of your own, like personal time in order to work on it because a lot of us don't want to really do our school work."
	Choice	Students were given activities that provided them choice in topic and/or design.	"It's engaging because it gives us a lot more freedom, because we didn't necessarily have like, this is how you have to build the catapult. We had the opportunity to make it with the resources and figure out how we wanted it to look." "We got to choose what topic we wanted to focus on."

Disengagement	Passive Learning	The students were sitting and listening and not active in building knowledge.	"But like pure note days where like, I'm not physically doing something or I'm not mentally there. I just tend to start dazing off and falling asleep."
	Lack of Confidence	The students did not feel confident with their knowledge and their abilities to conquer the difficulties.	"When you are not good at something, you just quit."
	Lack of Personal Choice	The students did not have the choice in their task selection.	"I just thought it wasn't as engaging because, for me personally, I just like having a personal experience and this was something that was predetermined."

Appendix I

Stats Medic Lesson

Name: _____ Hour: _____ Date: _____

Is it smart to foul at the end of the game?

In the 2005 Conference USA basketball tournament, Memphis trailed Louisville by two points. At the buzzer, Memphis's Darius Washington attempted a 3-pointer; he missed but was fouled, and went to the line for three free throws. Each made free throw is worth 1 point. Was it smart to foul?

1. What are all the possible ways the shots could fall (e.g. make-miss-miss, etc.)?

2. Darius Washington was a 72% free-throw shooter. Find the probability that Memphis will win, lose or go to overtime. When you have found the probabilities put them in the table in #3.

Win	Lose	Overtime

3. Prior to watching each shot, calculate the probability that Memphis wins the game in regulation, loses the game in regulation, or sends the game into overtime.

		Shots Remain.	Probability Memphis Win	Probability Memphis Lose	Probability Overtime
75	73				
75					
75					

4. Washington is a 40% 3-point shooter. Do you think Louisville was smart to foul? Why or why not?

STATS MEDIC

Name: _____ Hour: _____ Date: _____

Binomial Random Variables

Important ideas:

Check Your Understanding

1. For each of the following situations, determine whether or not the given random variable has a binomial distribution. Justify your answer.

   a. You play a game of Whack-a-Mole. From playing this game in the past, you know that you have an 80% probability of whacking the mole before it drops back into its hole. The moles pop up randomly and your ability to whack any particular mole is not affected by whether or not you whacked the previous mole. There are 20 moles to be whacked during one round of the game. Let X = the number of moles you are able to whack.

   b. Next you play Skee Ball. You know that you have a 10% probability of getting any given ball in the 10,000-point hole. Let Y = the number of balls you must roll until you get one in the 10,000-point hole.

2. Now you play a game called Tsunami Duck Pond. In Tsunami Duck Pond there are 100 ducks that get pummeled by tidal waves. You have to reach your hand into the tsunami and select a duck. If there is a star on the bottom of the duck, you win. The game claims to have 20 ducks with stars among the 100 ducks. After each round you must place the duck back in the tumultuous water. Let W = the number of times you win if you play this game 10 times.

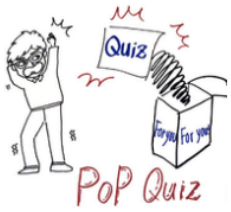
   a. Explain why W is a binomial random variable.

   b. Find the probability that you win exactly 3 times.

Name: _____ Hour: _____ Date: _____

	A	B	C	D
1	○	○	○	○
2	○	○	○	○
3	○	○	○	○
4	○	○	○	○
5	○	○	○	○

Pop Quiz!



It's time for a pop quiz! We hope you are ready. The quiz consists of 5 multiple-choice questions. Each question has four answer choices, labeled A through D. Now for the bad news: you will not get to see the questions. You just have to guess the answer for each one.

1. Bubble in an answer for each question for the pop quiz. Number correct = _____
2. Let X = number of correct guesses. Is this a binomial setting? Explain.

3. Calculate the probability of getting exactly 2 correct. Show your work.

4. Fill in the table below showing the probability of getting exactly *X* correct.

# correct (*X*)	0	1	2	3	4	5
Probability						

5. Find and interpret the mean of the distribution. Show your work.

6. Find and interpret the standard deviation of the distribution.

7. What is the probability of getting at most 3 correct?

8. What is the probability of getting 3 or more correct?

Name: _____ Hour: _____ Date: _____

Describing Binomial Distributions

Important ideas:

Check Your Understanding

Are you more likely to win a random drawing if you crinkle the paper that contains your name before putting it into the drawing box? A curious student conducted a study to investigate. The student took 100 equal sized slips of paper and crinkled 25 of them before putting them all into a box. After mixing well, they asked an uninformed person to select a winner at random. The student noted if the slip was crinkled. The slip was returned to the box, mixed well, and asked another uninformed person to select a winner at random. This process was repeated 10 times. Let Y = the number of times that a crinkled paper was selected.

a. Does this setting represent a binomial distribution? Explain.

b. Use technology to make a histogram of the probability distribution of Y. Describe its shape.

c. Calculate and interpret the mean of Y.

d. Calculate and interpret the standard deviation of Y.

Appendix J

Gummy Bear Experiment

The Gummy Bear Project **Due:**

Group # _____ Members:

The purpose of this experiment is to provide you the opportunity to practice the principles of experimental design. Within your group, you will need to design a **controlled** experiment to test a factor that will effect how far gummy bears will "fly" from a catapult. (The easiest factor to test will be the angle of the launch.) Below are the parameters that you MUST follow.

Materials given: **No other materials may be used without prior approval of Mrs. Gile**

2 tongue depressors
1 rubber band
bag of gummy bears (minimum of 30 used)
a flat surface
tape measure
masking tape
markers & pencils are group provided

Factor(s) tested:

The easiest factor to test is the launch angle of the bears. This is done by placing books beneath one end of the flat surface to elevate the catapult to different angles. **If you are testing one factor, the factor should have three levels.** If you wish to test other factors, prior approval **MUST** be obtained from Mrs. Gile.

Response variable:

How many treatments do you have?

Explain how you will utilize randomization? (Pretend that these gummy bears are actually people.)

What experimental design will you use? Explain.

What controls do you need?

State your launch procedure

What could possibly go wrong?

What do you expect to happen?

Launch

You will have the remainder of the class period to launch your bears- I suggest allowing yourself at least 45 minutes. If done correctly, it will take that long. You must turn in your 30 (minimum) bears used in the experiment at the end of class. Please return tape measures, tape, flat surface, etc, to proper places. (Perform a few practice launches before starting the experiment for proof of concept.)

Report:

The group members can create a typed report, a Google Slides, a poster, a YouTube video or any other presentation of their results that they will share with the class.

1. Cover Page

The cover page needs to include a title, all group member names, and a fun picture.

2. Introduction

Explain the purpose of the experiment, be sure to include experimental units, Factors, and treatments. Describe your experimental design.
Describe your hypothesis for what you expect to happen when you change the angle of launch.
Explain the components of a well-designed experiment and how they apply to your design.

3. Controls –

The grade for this section will be based on teacher observation of the experiment during class. Students need to explain the controls that were put in place to be sure that the only factor tested was the angle of launch or the one chosen by the group and approved by Mrs. Gile.

4. Randomization process & list of bears in treatments

Explain the randomization process that you used to place the bears into treatments. Include a picture of the bears.

5. Raw data -chart of distances of all 30 bears in the treatment groups

6. Summary statistics

All summary statistics we have studied in unit 1 for quantitative variables must be evaluated for your data.

7. Graphical displays

All graphical displays studied for Unit 1 Quantitative data must be used for this. The graphs should be computer generated with the treatments clearly separated in different graphs.

8. Interpretation of results

Write up the observations of the 3 treatments.
Make sure to compare graphs and summary statistics and state statistically what that means.
Was your hypothesis correct?

9. What did go wrong? What would you do differently?

Reflect on your experiment. Did you miss any controls that you can think of?
What would you differently next time?
Did this meet what you expected when you were planning your experiment?
What went wrong?
How did the team work together?

Also include this page (**completed)**

Gummy Bear Grading Guide

		Who did this part?	
Cover page	(5)	_____	_____
Introduction	(10)	_____	_____
Randomization	(10)	_____	_____
Controls	(15)	_____	_____
Raw data	(5)	_____	_____
Summary Statistics	(10)	_____	_____
Graphs	(10)	_____	_____
Interpretation of results	(20)	_____	_____
What went wrong/do differently?	(10)	_____	_____
Group worksheet	(5)	_____	_____
Project Grade:			_____

Comments:

Fill out the peer and self-evaluation form in the Google Classroom

Adapted from several versions of this project received at APSI and on the internet.

Appendix K

Research Bias Project

AP Statistics First Semester Project: Response Bias

The Project: You and your partner (or you by yourself) will design and conduct an experiment to investigate the effects of response bias in surveys. You may choose the topic for your surveys, but you must design your experiment so that it can answer at least one of the following questions:

- Can the wording of a question create response bias?
- Does providing additional information create response bias?
- Do the characteristics of the interviewer create response bias?
- Does anonymity change the responses to sensitive questions?
- Does manipulating the answer choices/order of answer choices change the response?
- Can revealing other peoples' answers to a question create response bias?

Proposal (25 points):

- The proposal is due: _Feb 23_ _.
- The proposal will be worth 25% of the grade, so don't treat it casually.
- If the proposal isn't approved the first time, you will need to resubmit it for a reduced grade. You must attach the original proposal to any resubmissions.

In your proposal, you should:

- Describe your topic and state which type of response bias you are investigating.
- Describe how you will obtain your subjects in an unbiased manner (minimum sample size is 50). This must be practical!! Your population does not need to be from school, nor should you interrupt any classes.
- Describe what your questions will be and how they will be asked, including how you will incorporate the principles of a good experiment and avoid potentially confounding variables. You should also indicate what your hypotheses are. Convince me that you have a good design!

Presentation (75 points):

- The poster/slides/YouTube Video is due: _March 14__.
- The key to a good statistical poster is communication and organization. Make sure all components of the poster are focused on answering the question of interest.
- The poster should be standard sized and not on foam board. Make sure the poster is light enough to be hung on the wall.

The poster/slides/YouTube Video should include:

- Title (in the form of a question).
- Introduction. In the introduction you should discuss what question you are trying to answer, why you chose this topic, and what your hypotheses are.
- Data Collection. In this section you will describe how you obtained your data. Be specific.
- Graphs and Summary Statistics. Make sure the graphs are well labeled, easy to compare, and help answer the question of interest. The graphs should "stand alone"!
- Discussion and Conclusions. In this section, you will state your conclusions including the scope of inference. You should also discuss any errors you made, what you could do

to improve the study next time, and any other comments based on your own critical reflection on the project.

- Live action pictures of your data collection in progress.
- Each pair (or individual) will be required to give a 5 minute oral presentation to the class. Both members need to participate equally and should be prepared to answer questions.

Response Bias Project	4 = Complete	3 = Substantial	2 = Developing	1 = Minimal
Intro	• Describes the context of the research • Has a clearly stated question of interest • Provides a hypothesis about the answer to the question of interest • Question of interest is of appropriate difficulty	• Introduces the context of the research and has a specific question of interest • Suggests hypothesis OR has appropriate difficulty	• Introduces the context of the research and has a specific question of interest OR has question of interest and a hypothesis	• Briefly describes the context of the research
Data Collection	• Method of data collection is clearly described • Includes appropriate randomization • Describes efforts to reduce bias, variability, confounding • Quantity of data collected is appropriate	• Method of data collection is clearly described • Some effort is made to incorporate principles of good data collection • Quantity of data is appropriate	• Method of data collection is described • Some effort is made to incorporate principles of good data collection	• Some evidence of data collection
Graphs and Summary Statistics	• Raw data is included in a two-way table (categorical data) or in two lists (quantitative data) • Appropriate graphs are included • Graphs are neat, easy to compare and clearly labeled, including clear identification of treatments • Appropriate summary statistics are included in discussion (e.g., percentages for categorical data, means for quantitative data)	• Appropriate graphs are included (to help answer the question of interest) • Graphs are neat, clearly labeled, and easy to compare • Appropriate summary statistics or raw data are included	• Graphs and summary statistics are included	• Graphs or summary statistics are included
Conclusions	• Uses the results of the study to correctly answer question of interest • Discusses what inferences are appropriate based on study design • Shows good evidence of critical reflection (discusses possible errors, shortcomings, limitations, alternate explanations, etc.)	• Makes a correct conclusion • Discusses what inferences are appropriate or shows good evidence of critical reflection	• Makes a partially correct conclusion • Shows some evidence of critical reflection	• Makes a conclusion
Poster, Presentation, & Communi-cation	• Has a clear, holistic understanding of the project • Poster is well organized, neat and easy to read	• Has a clear, holistic understanding of the project, but poster is unorganized, lacks pictures, isn't visually appealing	• The poster and oral presentation have several problems	• Communic ation and organizatio n are poor

	• Poster included pictures of data collection in progress and is visually appealing • Oral presentation is well organized	or oral presentation is not organized		

Note: A score of 0 is possible in each category.

Adapted from Josh Tabor's project found here: https://www.statsmedic.com/post/response-bias-project

Appendix L

Final Choice Board

AP Statistics Final Project Choice Board
Your final grade for the year will be based on various projects. This assignment will be worth a quiz grade, a test grade, and your final exam- each will be 100 points. Your grade will be determined by the number of projects you complete and the quality of your work. You will choose from the list below. You can choose as many as you like, but you cannot earn more than 300 points.

Your final deliverable will be turned in electronically to Google Classroom. Some projects will be group activities and others will be individual. Only have one person turn in the group project, but he sure that all names are present on the project to receive full credit.

CHOICES:

1. ***Reference Pack for One Unit- 100 points (group of 3)- YOU MUST SIGN UP WITH GILE***

There were nine units in this course. Your assignment will be to create a resource pack to help future students review the material in one specific unit. You must include:

- List of formulas
- Vocabulary List
- Diagrams
- Key Topics and Learning Goals
- 6 multiple choice questions (with solutions)
- 1 FRQ question (with worked out solution)

Note: Your MC and FRQ cannot come directly from our notes or assignments as those already exist. The purpose of this resource is to summarize the unit and provide additional practice for future AP Statistics students.

2. **Data Collection- 100 points (groups of 3)**

Through observation or experimentation, collect a sample of *quantitative data* from a population. Obtain at least 60 values. Try to select data from a meaningful population. Your topic must be approved by Mrs. Gile. The project should include the following components:

- An introduction to the project. Include the purpose of the project in the introduction.
- A description of the nature of the data. What do the values represent? Remember the data must be quantitative in nature.
- A description of the sampling method used to collect the data and the sampling process used.
- An explanation of the population your data represents and identify possible sources of bias or error based on your method.
- Raw data- give a list of all of the data collected from your sample
- Report the summary statistics- sample size, the 5-number summary, the mean, range, standard deviation, variance.

- Separate your data into two groups for comparison purposes, such as tall/short, freshmen/sophomore, etc.
- Create a frequency table, stemplot, box and whisker plot, histogram, and dotplot to show your data and then also show it spit into the comparison groups.
- Do statistical inference on your data and display the steps and results.
- A conclusion to the project. Write in paragraph form any conclusion or inference that may be made from the analysis of your data. Cite your graphs and statistics as reasons for your conclusion.

3. Writing a Questionnaire- 50 points (group of 3)- NEEDS APPROVAL

Pick a topic of interest to you and write a questionnaire that contains at least 10 questions about this topic. Give the questionnaire to three different people and ask them to complete it (You need to turn in these results in your project). Look at the results of these questions and get feedback from your three people on the wording, then edit and reword your questions to collect the data that you are interested in knowing. Then pick a random sample of 50 or more people from an appropriate population and ask them to complete the questionnaire (these results must also be included). Analyze and summarize the results and how you carried out the random sampling, including graphical displays. The original and updated questionnaire should be included and an explanation of why you made the changes. Can you make any inferences from your results? Did you feel that your results were biased in any way and if so, why? If you were to repeat this survey, how would you change your procedure(s)? Explain how you picked your random sample. Provide details.

4. Research Study Analysis- 100 points-individual

Select a research article from a peer-reviewed journal. Write (one to two pages, typed, double-spaced- 12 point) an analysis of how the study was done. *This is to be an analysis, not just a summary of the article.* Include:

- An explanation of what the study was about (NOT JUST ONE SENTENCE)
- Methods that were used for data collection and an explanation of those methods
- A summary of the design of the methods used in the study and whether you think this was a valid design and why
- The conclusion that was made from the study
- The trustworthiness of the study- did you trust their results? Why or why not?
- Any additional things that you feel are necessary

5. Tootsie Pop- 50 points (groups of 4)

A famous commercial from the 70s and 80s asked how many licks it took to get to the center of a tootsie pop. You will conduct an experiment to determine this number. Your experiment must test at least 10 tootsie pops. You will submit a write-up to include your methods, data, and conclusion. Include graphs and pictures or videos of your participants getting to the center. Keep track of the licks carefully!

6. Create a fair die- 50 points (groups of 2)

Make two cubes out of paper or clay. Label the faces 1 – 6 (or in another way that you choose). Working with a partner, toss your cube 100 times and keep a tally of the results. In your presentation you will include:

- A detailed description of your process to make the dice.
- Pictures or a video of your testing your dice.
- The data that you collected.

- A chi-square test for each die that determines whether the die is fair
- A summary of the results and what you would do differently next time

7. Who is the best athlete? – 50 points (individual)

For your project, you will research statistics about two people who played the same position in the sport of your choice. You will analyze the data to determine, in your opinion, who is the best, then you will create a report with a visual display that you feel presents your position and convince others.

First, pick a sport and then a position. Once you choose the sport and position, you will choose a criterion that makes one player better than the other, i.e. consistency, performance, growth. Then choose two players and gather data for their **three** statistics for at least **ten years**. Then you will analyze your data based on your criterion and create a presentation of your findings and analysis to include:

- Charts of the two athletes THREE statistics with data for each year – include the year as a label for both athletes. Below is one example.

Pitcher 1 Pitcher 2

Year	ERA	Wins	Strikeouts		Year	ERA	Winis	Strikeouts
1990					1990			
1991					1991			
1992					1992			
1993					1993			
1994					1994			

- Calculate the 5-number summary, IQR, range, mean, and standard deviation for each stat
- Include graphs to compare the players in their THREE statistics. (histograms, stemplots, time plots, boxplots)
- Compare and describe the results for both athletes. Who is better? What criteria did you use to decide and what data proves your point? Make sure you include descriptions of the graphs and anything that may have been unusual in the data.

8. Write an AP Statistics Song and Create a YouTube Video- 100 point – (groups of 4)

For this you will write and create a parody song with statistics lyrics and create a video for the song. You must turn in your song lyrics typed out and have an engaging video that includes all the group members participating in it and post to YouTube. The song lyrics must be original and you must include some learning that you did in the class. Make it fun so I can use it next year!

9. AP Statistics Memes – 50 points (groups of 2)

Create five of your own original memes with pictures of members from your group or that your group made that relate to Statistics in some way. These cannot be ones that I can readily find on the internet (Trust me, I try to find them yearly and often save them to my phone or computer). Points will be given for creativity and effort put into making them.

Appendix M

Skew The Script Notes

Name: _____

AP Statistics Handout: Lesson 3.1

Topics: explanatory/response, describing scatterplots, correlation coefficient (r), causation

Lesson 3.1 Guided Notes

Explanatory and response variables

Bivariate data: data with _____ variables. Two quantitative variables are visualized in a _____

Income and Food Access Example (H.E.B Grocery Stores) *

Zip Code	Grocery Store Location	Average Household Income (x)	Organic Vegetables Offered (y)
78204	South Flores	$71,186	36
78207	N. Rosillo st	$34,234	4
78204	Nogalitos st	$71,186	28
78201	Frederickburg rd	$48,760	31
78212	Olmos	$78,096	78
78202	New Braunfels	$40,506	14
78237	Castroville	$38,166	12
78228	Culebra rd	$50,398	18
78227	Marbach rd	$49,437	38
78240	Babcock rd	$66,073	84
78230	Wurzbach rd	$86,566	61
78251	W Loop 1604 N	$78,176	56
78238	Bandera rd	$59,154	62
78223	S.New Braunfels	$50,252	44
78221	SW Military	$48,364	26
78224	S Zarzamora	$56,274	29
78220	W.W. White rd	$41,318	15
78209	East basse rd	$125,145	95
78216	San pedro	$65,911	18
78223	S.E Military dr	$50,252	65
78218	Austiin hwy	$53,945	50
78213	West Avenue	$59,072	35
78227	Valley Hi dr	$49,437	36
78244	Foster dr	$72,080	28
78231	N.W Military	$108,486	95
78239	Montogomery	$70,530	46
78217	Perrinbeiter rd	$57,199	29
78251	FM 471 west	$78,176	73
78250	Guilbeau rd	$78,288	53
78230	De Zavala	$86,566	86
78247	Thousand oaks	$84,181	68
78247	O'Connor rd	$84,181	56
78251	Potranco rd	$78,176	85
78247	Bulverde rd	$84,181	86
78248	NW Loop 1604	$135,547	93
78232	18140 San Pedro	$92,946	82
78249	9238 Loop 1004	$77,894	96

Using this data from San Antonio, TX, we will explore whether there is a relationship between neighborhood income and access to organic items at local grocery stores.

Explanatory (independent) variable: the variable that predicts, explains, or influences a trend in the response variable. This is the _____.

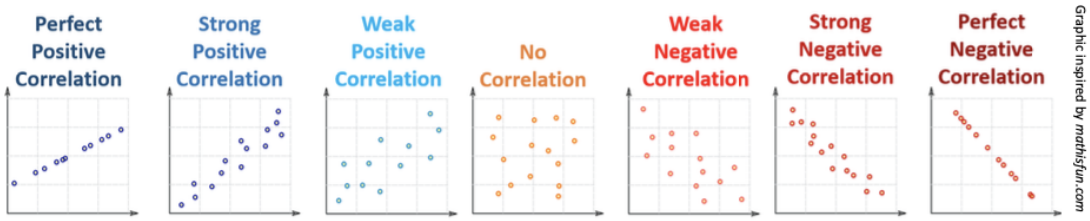
Response (dependent) variable: the measured outcome. Responds to trends in the explanatory variable. This is the _____.

In this example, which variable is the explanatory variable? Why?

In this example, which variable is the response variable? Why?

*Dataset compiled by student Linda Saucedo, Fall 2019

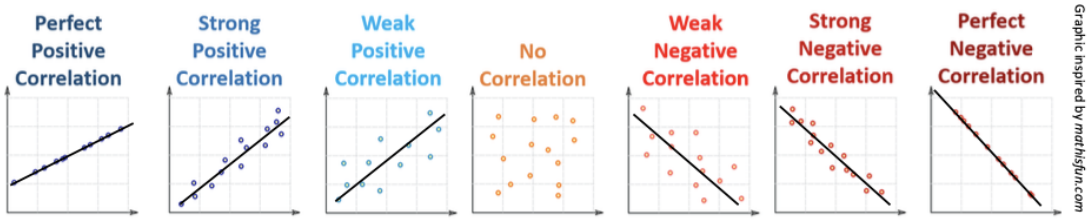
Describing scatterplots



Correlation: measures how two variables are _____.

Positive correlations: as the x values increase, the y values also tend to _____.

Negative correlations: as the x values increase, the y values tend to _____.



Least Squares Regression Line (LSRL): a straight line that roughly puts half of your data _____ it and half _____ it.

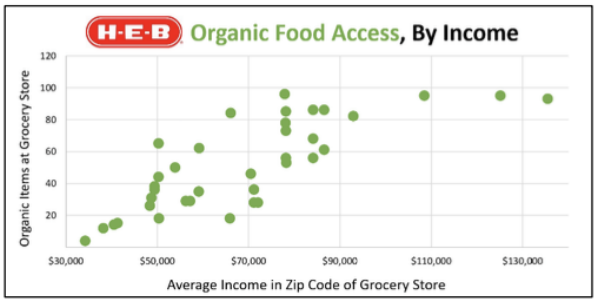
- More formal definition coming next lesson.

Strong correlations: data is _____ to the LSRL

- The LSRL is a _____ for the data
- If you used the LSRL to predict new data, you would make _____.

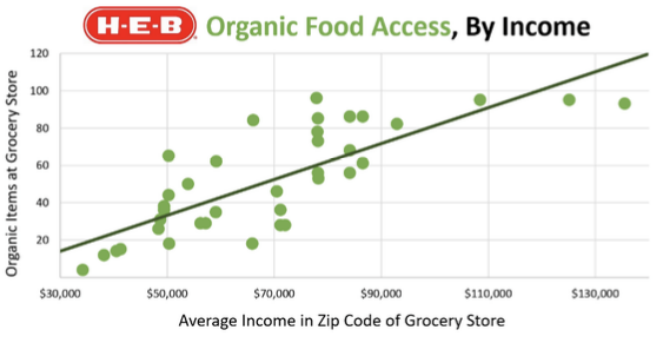
Weak correlations: data is _____ from the LSRL

- The LSRL is a _____ for the data
- If you used the LSRL to predict new data, you would may be _____.



Direction:

Strength:



C – Context

D – Direction (positive/negative)

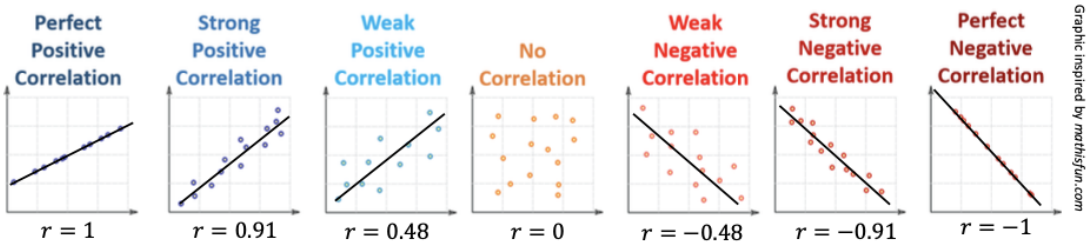
O – Outliers

F – Form (linear/non-linear)

S – Strength (strong/moderate/weak)

<u>Put it all together:</u> Describe the relationship between average household income in a zip code and the number of organic vegetables offered at the local grocery store…

Correlation coefficient (r)



<u>Correlation Coefficient (r):</u> A number between _____ that tells you the strength and direction of a correlation.

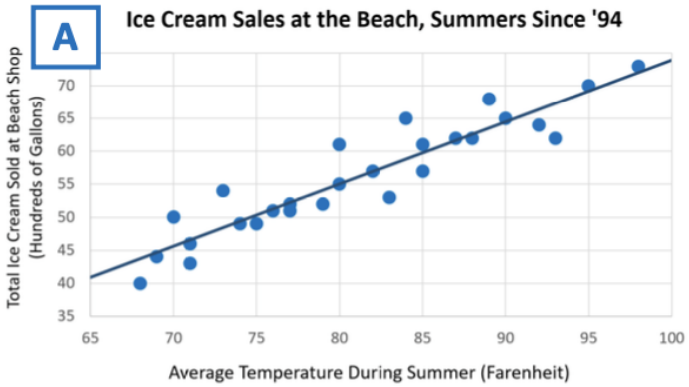
Strength:
r close to 0 → _____ correlation
r close to -1, 1 → _____ correlation

Direction:
Negative r value → _____ correlation
Positive r value → _____ correlation

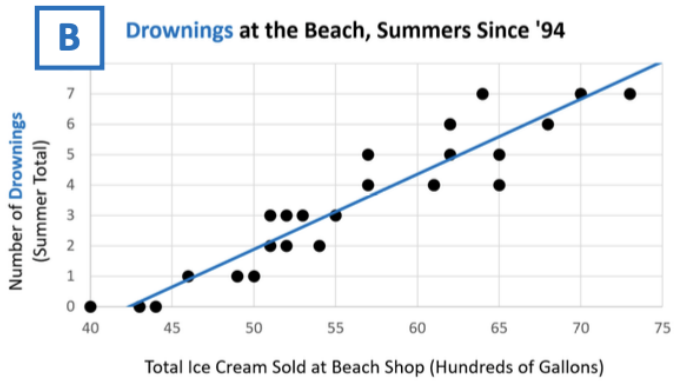
Lesson 3.1 Discussion

From 1994-2020, a statistician collected three pieces of data each summer at a beach:

1. The average temperature
2. The amount of ice cream sold at the beach shop
3. The amount of drownings



A) Discussion Question: Describe the relationship between temperature and ice cream sales. Does this relationship make sense? Why or why not?



B) Discussion Question: Describe the relationship between ice cream sales and drownings. Does this relationship make sense? Why or why not?

Big Idea:

Correlation ___ Causation

Coincidental Correlations, courtesy of Tyler Vigen: https://www.tylervigen.com/spurious-correlations