Middle School Students' Mathematics Attitude Profiles: Real-Time Origins and Classroom Implications[1]

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Abstract

Interpreting findings from the numerous research studies that identify macrovariables linked with attitudes toward mathematics and their connections to achievement is complicated by the lack of theoretical clarity around the construct of attitudes. This mixed-methods, multiple-case phenomenological study expands the body of research that describes the origins of students' attitude profiles. Moreover, this study used the experience sampling method (ESM) to capture real-time microvariables in the classroom that impact students' attitudes toward mathematics as described by students in their voices. The use of the ESM increased the ecological validity and reliability of students' statements, compared to questionnaires and interviews alone, while using many moments in time rather than a single measurement. Seventy-five students participated in the study representing one low-, one middle-, and one high-performing middle school in New Hampshire. I coded 3,988 students' statements from 477 randomly captured classroom moments. Quantitative results suggest students' attitudes toward mathematics change over time, the number of attitude changes does not differ across performance levels, and the distribution of students within various attitude profiles differs across performance levels. Using a three-dimensional theoretical framework with eight attitude profiles and a holistic and systematic coding process, I discovered eight themes used to develop detailed, rich descriptions of the essence of each attitude profile. Students' perceived competence was linked to the successes

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they experienced daily. Tests and quizzes dominated classroom activities among all four of the eight attitude profiles that contain a negative emotional dimension.

Keywords: mathematics, attitudes, experience sampling method (ESM), middle school

MIDDLE SCHOOL STUDENTS' MATHEMATICS ATTITUDE PROFILES: REAL-TIME ORIGINS AND CLASSROOM IMPLICATIONS

Federal and state policymakers cite strong science, technology, engineering, and mathematics (STEM) educational pathways in elementary, secondary, and postsecondary education as a key component to a strong STEM-capable workforce in the United States (National Science Board [NSB] & National Science Foundation [NSF], 2020). According to NSB and NSF (2020), the United States has shown minimal growth in national mathematics assessments over the past decade and continues to rank in the middle tier of advanced economies in international mathematics and science assessments. However, the assessment debate remains complex.

Ravitch (2014) argued concerns over the poor performance of students on mathematics assessment in the United States are unfounded, as scores on the National Assessment of Educational Progress (NAEP) are at all-time highs for students who are White, Black, Hispanic, and Asian, while also showing dramatic increases over the past 2 decades. Immediately following the passage of the No Child Left Behind Act of 2001, test scores on NAEP increased but have remained flat for an entire decade after 2007 (Ravitch, 2020). As such, many educational reformers in the United States who advocate for high-stakes assessment, accountability, charter schools, and the privatization of the U.S. school system use comparisons on international assessments to argue the United States has lost its competitive edge (Ravitch, 2016).

Despite poor performance on international assessments in mathematics, the United States has historically ranked well on the Global Competitiveness Index (GCI) and continues to do so. The GCI seeks to capture various factors believed to contribute to the productivity and prosperity of a nation such as infrastructure, higher education and training, innovation, health, and primary education (Schwab, 2016). The GCI 4.0 was developed in 2018 and comprises 103 individual indicators that measure national competitiveness and outline the factors and attributes that drive productivity (Schwab, 2019). The United States ranked second in the 2019 report (Schwab, 2019).

The United States continues to lead the world in research and development. Globally, the United States performs the largest share of research and development, accounts for the largest share of industry output, graduates and awards the largest number of science and engineering doctoral degrees, and accounts for a significant share of science and engineering research articles and citations (NSB & NSF, 2020). However, measuring the magnitude of contributions from individuals educated within the United States versus individuals who received their primary education outside of the United States, and who attended undergraduate or graduate institutions within the United States and remain in the country after graduation, is complicated.

More than half of the doctorate recipients in engineering, mathematics, computer science, and economics are foreign-born noncitizens; many stay in the United States after graduation and account for a sizeable share of the science and engineering employment (NSB & NSF, 2020). The Business Higher Education Forum (BHEF, 2011) noted too few students in the United States are interested in pursuing careers in STEM fields, only approximately half of those who start their studies in STEM fields graduate in those fields, and STEM worker shortages will be exacerbated by the retirement of current workers in those fields. Despite recent efforts to emphasize STEM instruction in the United States, attrition within the U.S. educational system in STEM continues to hinder the ability to produce enough workers to fill the STEM demand (BHEF, 2017).

Problem Statement

Between 2018 and 2028, employment for operations research analysts, mathematicians, and statisticians is projected to grow at 25.6%, 26%, and 30.7%, respectively, due to the availability of big data and the demand to use statistical analysis to make informed business, health care, and policy decisions (Dubina et al., 2019). ACT (2017) noted little change in STEM interest among ACT-tested high-school graduates between 2012 and 2017. Moreover, of those students interested in pursuing a STEM career, only .17% and .43% were interested in pursuing a career in science or mathematics education, respectively (ACT, 2017).

According to ACT (2017), 23% of ACT-tested high school graduates who had an expressed interested in STEM met the ACT STEM benchmark, and 20% of those students who had a measured interest in STEM, met the ACT STEM benchmark, whereas 33% of those students who had both an expressed and measured interest in STEM met the benchmark. ACT (2017) concluded expressed or measured interest in STEM is associated with higher levels of students' college readiness in STEM fields compared to those students who do not have either an expressed or measured interest in STEM fields. Additionally, attitudes were associated with mathematical achievement, as demonstrated by Hattie's (2009) meta-analysis of 288 studies and interest in the field.

Students often choose different educational pathways and careers based on their mathematics self-beliefs (Organization for Economic Co-operation and Development [OECD], 2013). Results from successive Trends in International Mathematics and Science Studies (TIMSS) show strong positive relationships between mathematical achievement and students' attitudes toward mathematics. However, at the same time, they tend to show drops in positive attitudes toward mathematics from fourth to eighth grade.

On the 2015 TIMSS assessment, 38% of eighth-grade students reported they do not like learning mathematics compared to 19% of fourth-grade students (Mullis et al., 2016). Although the percentages in the "like learning mathematics" category were similar across fourth and eighth grade, the percentage of students in the "very much like learning mathematics" category dropped from 46% in fourth grade to 22% in eighth grade (Mullis et al., 2016).

Mathematical Attitudes

Educators have ingrained the concept of attitude into their everyday vernacular. The development of the construct of attitude, as it applies to mathematics education, is essential to understand and interpret research findings in the field. Aiken and Dreger (1961) were among the first researchers to spend significant time researching students' attitudes toward mathematics.

From a historical standpoint, it is interesting to note that Aiken and Dreger (1961) analyzed paragraphs written by 310 college students, describing their attitudes toward mathematics, and reduced that work to an attitude scale containing a dichotomy of 10 items representing positive attitudes and 10 items representing negative attitudes. Subsequently, much research has focused on establishing causal relationships between attitudes and performance and uncovering the macrovariables having the greatest impact on attitudes (Hannula et al., 2016; Zan & Di Martino, 2007).

As Zan and Di Martino (2007) noted, much of that research is contradictory and confusing due to a lack of careful attention to the construct of attitudes (i.e., the construct is being used differently across various research studies). Moreover, questionnaires and measurement scales used to judge students' attitudes are often chosen by others and sometimes irrelevant to students (Hannula et al., 2016). The integration of qualitative approaches in attitude research studies allows students to express what is most important to them while ignoring the irrelevant (Hannula et al., 2016).

Student Mathematics Attitudes and Learning

Aiken and Dreger's (1961) early work, together with the strong belief that attitudes play a crucial role in learning mathematics (Neale, 1969), resulted in several research studies on the topic. Multiple studies, syntheses of studies, and meta-analyses identify numerous macrovariables impacting students' attitudes toward mathematics or associate attitudes with performance (Aiken, 1976; Choi & Chang, 2011; Di Martinio & Zan, 2009; Hattie, 2009; Idil et al., 2016; Ma & Kishor, 1997; Mata et al., 2012; McLeod, 1992; Ruffell et al., 1998; Schofield, 1982; Wilkins & Ma, 2003).

Variables that impact students' attitudes toward mathematics or performance include teachers' attitudes toward mathematics, teachers' preparation, school climate, gender, parental educational levels, instructional techniques, motivation, and social support variables. Few, if any, studies focus on the day-to-day, real-time variables that impact students' attitudes toward mathematics. This study responded to the call for the development of qualitative approaches for measuring students' attitudes toward mathematics while identifying the origins of various attitude profiles (Hannula et al., 2016) in real time by testing a theoretical three-dimensional framework for attitudes toward mathematics.

Di Martino and Zan's Three-Dimensional Model for Attitude

Due to the lack of theoretical clarity on the construct of attitudes as it applies within mathematical research, Di Martino and Zan (2009) used a grounded theory approach based on the analysis of students' essays to develop a theoretical three-dimensional model for attitudes toward mathematics (see Figure 1). They drew upon the origins of attitudes in social psychology; Mandler's (1984) theory of emotions; McLeod's (1992) work on emotions, beliefs, and attitudes; and the addition of the construct of value in DeBellis and Goldin's (1999) work.

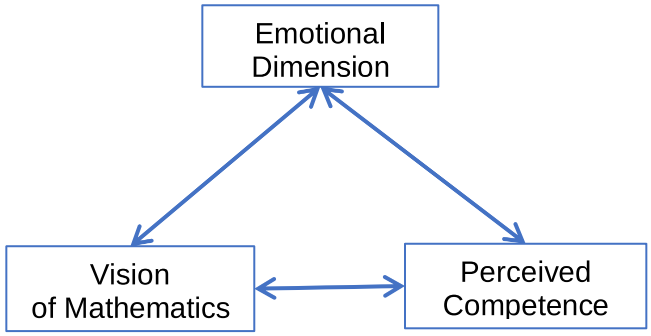
Di Martino and Zan (2009) suggested attitude toward mathematics can be considered negative when at least one component of a dimension is negative. The emotional dimension contains two components—positive and negative. The vision of mathematics dimension contains a relational component (positive) and an instrumental component (negative). Relational understanding refers to the ability to see mathematics as connections within and across ideas and extends to understanding why those ideas and procedures work. An instrumental understanding of mathematics refers to viewing mathematics as a set of procedures, algorithms, and rules to be followed with little focus on understanding the origins of the procedures or why they work. The perceived competence dimension contains a high (positive) and a low (negative) component. The two components of each of the three dimensions result in eight possible attitude profiles:

1. positive, relational (positive), high (positive) (PRH),
2. positive, relational (positive), low (negative) (PRL),
3. positive, instrumental (negative), high (positive) (PIH),
4. positive, instrumental (negative), low (negative) (PIL),
5. negative, relational (positive), high (positive) (NRH),
6. negative, relational (positive), low (negative) (NRL),
7. negative, instrumental (negative), high (positive) (NIH), and
8. negative, instrumental (negative), low (negative) (NIL).

As an instrumental understanding of mathematics and low perceived competence are considered negative attributes, there is only one profile, PRH, that contains no negative components.

Figure 1

Di Martino and Zan's Three-Dimensional Model for Attitude



Note. Figure 1 illustrates the interconnected dimensions of Di Martino and Zan's three-dimensional model for attitude.

Even though each dimension of Di Martino and Zan's (2009) framework contains a dichotomy, their work represents an important shift from viewing attitudes toward mathematics as solely negative or positive, as the model allows educators to effectively diagnose which dimension of a students' attitude profile is negative and develop appropriate intervention techniques.

Di Martino and Zan (2009) described attitude as a construct used by observers to understand the intentional actions of an individual rather than an inherent quality of an individual. McLeod (1992) stated belief and attitudes are relatively stable over time. Consistent with these findings, Wilkins and Ma (2003) found little change in students' notions of the nature of mathematics from seventh grade to secondary school. However, Di Martino and Zan's work indicated it may never be too late to change students' attitudes toward mathematics.

Capturing Students' Mathematics Attitudes in Real Time

This study added to the body of literature calling for qualitative approaches to measuring students' attitudes toward mathematics (Di Martino & Zan, 2009; McLeod, 1992) while describing the origins of various attitude profiles (Hannula et al., 2016) as outlined in Di Martino and Zan's (2009) framework. Using the experience sampling method (ESM), students recorded in real time the aspects of the classroom environment that impacted their attitudes toward mathematics as aligned to Di Martino and Zan's framework.

Larson and Csikszentmihalyi (1983) described the ESM as "a research procedure for studying what people do, feel, and think during their daily lives" (p. 21). In this study, students, while in mathematics classes, received signals through electronic devices that triggered them to answer a series of questions related to each of the dimensions of Di Martino and Zan's (2009) framework. The random signals captured a representative set of moments in time in the mathematics classroom where students recorded, in their voices, how they thought and felt about mathematics, and what happened in the classroom that was influencing those thoughts.

The ecological validity of questionnaires and interviews is often doubted as the data are collected outside the environment from the context referenced (Larson & Csikszentmihalyi, 1983). The encoding specificity principle suggested episodic memory is enhanced when information available at the time of encoding is also available at the time of decoding (Tulving & Thomson, 1973). Using the ESM allowed for the stability of conditions present during the encoding and decoding process. As students completed their journal protocols in real time, which were aligned to Di Martino and Zan's (2009) framework (see Appendix A), the location of the settings, classroom conditions, and likely the mental and physical states of the students remained constant. Moreover, the use of the ESM, compared to diary methods, mitigates differences between the historical reality and a student's later interpretation of that reality.

Significance of This Study

This mixed-methods phenomenological study explored a set of qualitative research questions aimed at understanding Di Martino and Zan's (2009) framework, the ways students experiencing their first middle-school mathematics course describe the real-time classroom origins that impact their attitude profiles, and how participating in the ESM study impacted their awareness of their attitudes toward mathematics. The use of the ESM resulted in detailed, rich descriptions of real-time classroom factors impacting various attitude profiles. Furthermore, descriptive statistics and frequency analysis were used to determine the extent to which students' responses fell within Di Martino and Zan's framework, the extent to which students' attitudes were stable throughout the study, and the distribution of students within each attitude profile disaggregated by school-wide performance levels in mathematics.

Results of this study can aid teachers in identifying the various classroom factors impacting students' attitudes toward mathematics. For example, this study showed tests and quizzes were the dominant classroom activities contributing to students' negative emotional states toward mathematics. Furthermore, even though students in all eight attitude profiles tended to exhibit positive self-perceptions as learners of mathematics, their perceived competence was highly linked to the successes they experienced.

There is a lack of substantial evidence that the mandates of large-scale annual assessments have resulted in sustained educational improvements (Ravitch, 2014). These large-scale assessments have created an overreliance on testing within the classroom that may be counterproductive to the challenges outlined herein. Results of this study can aid policymakers and educators in reshaping curriculum, pedagogy, and assessment in ways that facilitate a larger number of students developing positive attitudes toward mathematics, which in turn can help mitigate concerns about STEM worker shortages based upon projected future demands.

Literature Review

The concept of attitudes has its origins in social psychology, and several authors in the early 1900s defined social psychology as the scientific study of attitudes (as cited in Allport, 1935). The chronological development of the construct of attitude is particularly important to the methodology applied in this study. Throughout the early part of the 20th century, research focused on conducting robust quantitative procedures, including multivariate analysis studies, to determine which variables impacted attitudes toward mathematics and the extent to which these variables predicted performance.

These procedures allowed researchers to disentangle individual and group effects on response variables while accounting for variation both within and across levels, such as classrooms and classrooms within schools. However, even equipped with robust statistical techniques, conflicting findings have left researchers dissatisfied. Di Martino and Zan (2009) postulated the conflicting findings are due to a lack of consensus and careful development of the theoretical construct of attitudes. This lack of consensus has resulted in a shift in the call in the literature to focus on qualitative studies aimed at the development of the construct of attitude as it applies within mathematics (Di Martino & Zan, 2009) and uncovering the origins of various attitude profiles (Hannula et al., 2016).

Early Development of Attitudes

Psychologist Herbert Spenser used the concept of attitude in 1862 to refer to both mental and motor attitudes (Allport, 1935). Subsequently, Thomas and Znaniecki (1918) popularized the term attitude within social psychology and used the term to describe both responses and potential responses in a social world directed toward an object (Allport, 1935). Dewey (1922) suggested the common use of the terms attitude and disposition referred to something latent that is activated by a positive stimulus.

Allport (1935) examined common threads in several definitions to conclude "an attitude is a mental and neural state of readiness, organized through experience, exerting a directive or dynamic influence upon the individual's response to all objects and situations with which it is related" (p. 803). Allport (1935) noted the inherent difficulty of defining attitudes and suggested attitudes should include habits and only be considered approximations of true attitudes, as the mental state of an individual at the time an attitude scale is completed might differ from the individual's true state. This is consistent with Tulving and Thomson's (1973) encoding specificity principle and mitigated using the ESM in this study.

Early Origins of Attitudes and Mathematical Achievement

Aiken and Dreger (1961) were among the first researchers to study the relationship between attitudes toward mathematics and achievement measures, personality measures, and experiences with mathematics. They called for further studies focused on attitudes and mathematical achievement. In 1976, Aiken published his second synthesis of research on attitudes toward mathematics, noting more dissertations and articles on the topic had appeared between 1970 and 1975 than in the previous decade.

His synthesis pointed to several research studies indicating low but significant positive correlations between attitudes and achievement at all levels of schooling, with additional studies highlighting the importance of late elementary and early junior high grades on the development of attitudes toward mathematics. Additional studies showed attitudes toward mathematics and achievement were significantly related to a sense of personal worth, a sense of responsibility, high social standards, motivation, and decreases in the tendency to withdraw (Aiken, 1976).

However, Aiken (1976) criticized the use of "homegrown" attitude scales and the lack of proper statistical techniques used in a variety of the studies analyzed. The various instruments researchers have continued to use to measure attitudes toward mathematics remain criticized for a variety of reasons including: (a) questionnaire items might not reflect what is important for participants, (b) attitudes are treated as only positive or negative, (c) causal relationships are often inferred, and (d) there is little attention devoted to the factors regarding behaviors, beliefs, and emotions from which the construct of attitude is developed (Di Martino & Zan, 2009; McLeod, 1992). Aiken concluded attitudes toward mathematics are dependent upon course content, instructional methods, parental and peer support, interactions between students and teachers, and the methods measuring changes.

While researchers were focused on quantitative studies positioned within a positivistic epistemology seeking to establish causal relationships between attitudes and performance, a new paradigm began to emerge with influences from developmental psychology and cognitive psychology. Neale's (1969) study concluded attitudes toward mathematics only had a slight causal influence on learning mathematics; however, the study highlighted that schools, as institutions, can overpower the influences of attitudes toward learning, but the system needs to be redesigned to allow for more individualism. As the National Research Council (NRC) and the National Council of Teachers of Mathematics (NCTM) sought to reform mathematics curricula by placing a greater emphasis on process standards, researchers began to explore beliefs, emotions, and attitudes toward mathematics through qualitative approaches (McLeod, 1992).

Attitudes and the Affective Domain

Early studies on attitudes and mathematics focused on quantitative approaches and establishing causal relationships between attitudes and performance. Noting discontent in the literature with these traditional approaches, due to the lack of strong theoretical foundations, McLeod (1992) applied Mandler's (1984) theory to organize research on affect into three areas: (a) students hold beliefs about mathematics and themselves, (b) students experience both positive and negative emotions while learning mathematics, and (c) students develop positive or negative attitudes toward mathematics as they encounter similar situations over time.

The progression from beliefs, attitudes, and emotions involves an increase in affective involvement and intensity of response and a decrease in cognitive involvement and response stability (McLeod, 1992). The willingness to engage in the complexity introduced by considering including affective factors in the study of mathematical attitudes creates momentum to work on theoretical frameworks for analyzing the construct of attitude as it applies in mathematics and the greater use of qualitative techniques to link cognitive factors to the affective domain.

As an example, Hannula (2002), who believed Mandler's (1984) theory was too simplistic to capture less intense emotional states, developed an analytical framework for analyzing attitudes and changes in attitudes. The framework involved four aspects of attitudes and the psychology of emotions: (a) emotions aroused in the situation, (b) emotions associated with stimuli, (c) expected consequences, and (d) relating situations to personal values (Hannula, 2002). Hannula illustrated the framework through an ethnographic case study by following a student over 6 months and documenting the change in the student's attitude from negative to positive.

As theoretical models developed, researchers studied the variables impacting attitudes, beliefs, and performance in mathematics through quantitative studies. These studies, together with the qualitative work, enhanced researchers' understandings of students' attitudes toward mathematics. Before shifting the focus to the development of Di Martino and Zan's (2009) theoretical model for attitudes, it is important to look at some of the variables impacting attitudes, beliefs, and performance.

Variables Impacting Attitudes, Beliefs, and Performance

Numerous studies have examined the impact of mathematical attitudes on performance and the various variables impacting attitudes (Ma & Kishor, 1997). Research findings have varied, and a challenge in making meaningful generalizations stems from the lack of consistent use of definitions and constructs. Additionally, numerous variables impacting attitudes, beliefs, and performance have been studied, including (a) the relationship between attitudes and achievement, (b) gender, (c) grade level, (d) the time when tests are administered, (e) teachers' attitudes, (f) parents' attitudes, (g) school climate, (h) class level, (i) educational aspirations, (j) parental education level, (k) students' backgrounds, (l) motivation, (m) social supports, (n) instructional techniques, and (o) teacher knowledge.

Many of these variables are the types of variables referred to in this study as macrovariables. This study aimed to focus on microvariables—those variables that occur within the classroom on a day-to-day basis that have the potential to impact attitudes and that teachers can control. See Andrusiak (2018) for a detailed summary of many of these studies covering macrovariables. A couple of important meta-analyses have been developed from the large number of studies focused on the relationships between attitudes, beliefs, and performance (Hattie, 2009; Ma &Kishor, 1997).

Due to the lack of consensus in the literature about the relationship between attitudes toward mathematics and performance in mathematics, Ma and Kishor (1997) performed a meta-analysis of 113 studies. Their meta-analysis revealed four key findings for the attitudes in mathematics and achievement in mathematics relationship:

1. The overall mean effect size, .12, was statistically significant but not large enough to have practical implications for educational purposes.

2. Grade, ethnicity, sample selection, sample size, and date of publication had reliable effects on the relationship.
3. Gender did not have reliable effects on the relationship.
4. There was no reliable evidence of the interaction effects among gender, grade, and ethnicity on the relationship.

Hattie's (2009) meta-analysis of 288 studies on attitudes toward mathematics and science on performance resulted in an effect size of .36, leading Hattie to conclude that while developing positive attitudes toward school and subjects is desirable, having a positive attitude is also a correlate of achievement. Ma and Kishor (1997) suggested the small effect size for the relationship between attitudes and achievement was likely due to attitude measures at the time being crude approximations of true attitudes, measurement techniques needed to be refined, and previous researchers likely omitted indirect factors impacting attitudes.

Attitude as a Construct to Understand Actions

Due to the lack of theoretical clarity on the construct of attitude as it applies in mathematics and conflicting results on associations between attitudes and achievement in mathematics, Di Martino and Zan (2003) suggested researchers use multiple approaches when assessing attitudes. Importantly, they suggested researchers shift their focus from a normative approach to an interpretive approach where attitude is used as a construct by the observer to understand the intentional actions of an individual rather than an inherent quality of an individual (Di Martino & Zan, 2003). Furthermore, Di Martino and Zan (2009) suggested researchers embrace multiple definitions as different research problems call for different definitions.

Di Martino and Zan (2009) applied a grounded theory approach when analyzing nearly 1,500 autobiographical essays to discover a set of categories that fit how students described their relationships with mathematics. Data analysis revealed only 2.1% of the essays failed to refer to at least one of the dimensions in Figure 1 (Di Martino & Zan, 2009).

Summary

Attitude has its origins in social psychology. Early definitions focused on the cognitive aspect of attitudes and the preparation for a response to stimuli. Initial queries into attitudes in mathematics focused on establishing causal relationships between attitudes and performance in mathematics and identifying which variables had the greatest impact on performance (Andrusiak, 2018; Hattie, 2009; Ma &Kishor, 1997).

As inconsistent results developed across quantitative studies, mathematicians theorized the differing results were due to the varying treatment of the construct of attitudes. When the National Research Council and the National Council of Teachers of Mathematics placed a greater emphasis on process standards and affective domains in mathematics, researchers turned to qualitative approaches to develop theoretical models for the study of attitudes as they applied to mathematics education. Such constructs and models involved the addition of values, beliefs, and emotions together with cognitive components. Di Martino and Zan (2009) suggested attitudes should be a construct used by researchers to understand the intentional actions of an individual rather than an inherent quality of the individual and that varying definitions fit varying research agendas.

Although comparing results across studies is complicated by different uses of the construct of attitudes, researchers have identified numerous macrovariables that impact attitudes, beliefs, and performance in mathematics (Andrusiak, 2018; Hattie, 2009; Ma &Kishor, 1997). Furthermore, Hattie's (2009) meta-analysis suggested attitudes are associated with performance. Various studies seem to indicate the transition from elementary school to middle school is an important time in attitude formation (Mullis et al., 2016). Moreover, Mullis et al. (2016) indicated attitudes tend to decline from fourth to eighth grade. Although McLeod (1992) and Wilkins and Ma (2003) indicated attitudes remain relatively stable over time, Di Martino and Zan's work (2009) suggested it may never be too late to change students' attitudes toward mathematics.

Over time, various criticisms occurred in the literature regarding attitude studies as they applied to mathematics. Some of these concerns include the varying use of the construct of attitude, measuring attitudes with Likert scales and questionnaires containing items that may be irrelevant for students, and measuring attitudes outside the context the measurement tools reference, which results in approximate attitudes versus true attitudes.

Much of the new research on attitudes toward mathematics involves the use of qualitative methods. This study mitigated many of the concerns outlined by being intentionally clear about testing Di Martino and Zan's (2009) theoretical framework for the construct of attitudes and using the ESM to mitigate memory retrieval issues while having students fill out journal protocols while in the context they referenced. These journal protocols also contained open-response items so students could record what was relevant to them in their words. Moreover, this study responded to the call to determine the origins of various attitude profiles (Hannula et al., 2016) while filling a gap in the literature by focusing on the microvariables teachers can control on a day-to-day basis that impact students' attitudes toward mathematics.

Methodology

Students' self-beliefs about mathematics have an impact on their life decisions, educational choices, and ultimately their career pathways (OECD, 2013). Successive TIMSS show strong positive relationships between mathematical achievement and students' attitudes toward mathematics (Mullis et al., 2016) as does Hattie's (2009) meta-analysis of 288 studies. Additionally, Mullis et al. (2016) indicated students' attitudes toward mathematics tend to decline from fourth to eighth grade, and approximately twice the percentage of eighth-grade students report disliking mathematics compared to fourth-grade students on each successive TIMSS from 1995 to 2015. Studies as far back as Aiken's (1976) synthesis indicate the transition period from elementary to middle school is particularly important to the formation of students' attitudes toward mathematics.

Numerous studies and meta-analyses identify or cite macrovariables that impact students' attitudes toward mathematics and establish associations between attitudes and performance (Aiken, 1976; Choi & Chang, 2011; Di Martino & Zan, 2009; Hattie, 2009; Idil et al., 2016; Ma & Kishor, 1997; Mata et al., 2012; McLeod, 1992; Ruffell et al., 1998; Schofield, 1982; Wilkins & Ma, 2003). Traditional studies positioned in a positivistic epistemology have resulted in conflicting results, which have led mathematics educational researchers to theorize the conflicting results were caused by the lack of careful attention devoted to the construct of attitudes. Thus, a new call emerged in the literature for qualitative studies aimed at developing theoretical frameworks for attitudes toward mathematics.

Di Martino and Zan's (2009) framework ties many elements from the literature together while seeking to avoid the traditional positive-negative dichotomy applied to attitudes by using an emotional dimension, perceived competence dimension, and vision of mathematics dimension. These three dimensions result in eight potential attitude profiles. Hannula et al. (2016) called for research studies aimed at uncovering the origins of various attitude profiles.

Although a solid ontological argument can be made for students' piecing together fragments of various situations to form an approximate attitude profile, the use of the ESM allows students to describe, in their voices, the real-time classroom factors impacting their attitudes toward mathematics. As I sought to describe the origins contributing to various attitude profiles as students experienced their first middle-school mathematics course, a common phenomenon, I used a mixed-methods, multiple-case phenomenological study design. Di Martino and Zan's (2009) shift to using attitude as a construct for the observer to understand the intentional actions of an individual, rather than an inherent quality of an individual, is consistent with Moustakas's (1994) transcendental phenomenology, which focuses more on the descriptions of participants than the researchers' interpretations (Creswell, 2013).

Although attitudes have been associated with performance (Hattie, 2009), conflicting results from quantitative studies are well documented in the literature, including the stability of attitudes over time; thus, I preferred a mixed-methods approach. Such an approach is appropriate when the use of only a quantitative or a qualitative method is insufficient for answering the research questions and understanding the problem (Creswell, 2014). Descriptive statistics gave perspective to the present study and established context while allowing for the analysis of the extent to which students' responses fell within Di Martino and Zan's (2009) framework, the stability of attitudes over time, and the distribution of attitude profiles across various performance levels.

Research Questions

The positioning of this study within a postpositivistic epistemology was ideal for taking a scientific approach to answering the research questions. Rather than investigating a single reality, this study integrated logical and empirically oriented theories that valued multiple perspectives to assess the following research questions (Creswell, 2014):

- In what ways do students describe the real-time classroom origins of their emotional relationship with mathematics, their vision of mathematics, and their perceived competence with mathematics?
- What are the real-time classroom factors or origins contributing to the eight attitude profiles as defined in Di Martino and Zan's (2009) three-dimensional framework?
- In what ways do students describe their experiences participating in the study, the stability of their attitudes over time, and the impact of the ESM on their awareness of the real-time classroom factors impacting their attitudes toward mathematics?
- To what extent do students' responses to the ESM journal fall within Di Martino and Zan's (2009) framework?
- To what extent are students' attitude profiles stable throughout the study?
- Are there statistically significant differences in the distribution of students within each attitude profile across school performance levels?

Furthermore, the multiple perspectives provided by the methodology employed in this study aided in expressing a universal essence for each attitude profile without using a reductionist research method.

Research Design

I used a mixed-methods multiple case study phenomenological design by using the ESM, journal protocols, interviews, and descriptive statistics and frequency analysis. Creswell's (2013) data collection circle formed the basis for the research design. The circle represents a series of interrelated tasks that qualitative researchers engage in to answer emerging research questions. Moreover, the circle represents the multiple phases of research design and data collection that extend beyond conducting interviews and making observations (Creswell, 2013). These phases included: (a) locating the sites and individuals, (b) gaining access to the sites, (c) establishing rapport, (d) purposefully sampling, (e) collecting data, (f) recording information, (g) resolving field issues, and (h) storing data.

Sampling

I used maximum variation sampling to select participants based on schoolwide mathematics performance. Maximum variation sampling is a purposeful sampling technique that allows the researcher to maximize differences at the beginning of the study to increase the likelihood the study will discover and reflect multiple perspectives (Creswell, 2013). This was an ideal method for this study, resulting in detail-rich descriptions of each of the eight attitude profiles in Di Martino and Zan's (2009) framework through the discovery of common themes while also allowing for the analysis of the distribution of attitude profiles across performance levels.

Table 1

Distribution of Study Participants

School	ESM Study Sixth Grade	ESM Study Seventh Grade	Interviews Sixth Grade	Interviews Seventh Grade
WTMS				
Teacher 1—Block A				
Group 1		4		1
Group 2		4		
Group 3		5		
Teacher 2—Block A				
Group 1		6		
Group 2		7		1
Group 3		6		2
HTMS				
Teacher 1—Block A				
Group 1	2			
Group 2	2			
Teacher 1—Block B				
Group 1	3			
Teacher 1—Block C				
Group 1	4			
Group 2	3		2	
Group 3	3		1	
Teacher 1—Block D				
Group 1	1			
MTMS				
Teacher 1—Block A				
Group 1	5			
Group 2	5		1	
Group 3	4			
Teacher 1—Block B				
Group 1	4		2	
Group 2	4			
Group 3	3		1	

Note. WTMS, HTMS, MTMS = the researcher's coding for low-, middle-, and high-performing schools, respectively. ESM = experience sampling method.

I ranked all middle schools in New Hampshire, my home state, according to the percentage of students meeting or exceeding the achievement levels on the statewide annual mathematics assessments. I identified low-, middle-, and high-performing schools by which third of the ranking they resided, respectively. As this study involved extensive classroom time, I was not able to randomly select schools for participation. I contacted schools within each performance level until I identified one middle school from each performance level to participate in the study. The three middle schools that participated were coded as WTMS, HTMS, and MTMS, representing the low-, middle-, and high-performing schools, respectively. Coding protected the identity of the schools.

The common phenomenon for participants in the study was students were experiencing their first middle school mathematics class. Since different middle schools begin at different grade levels, participants were either sixth- or seventh-grade students. A total of 75 students participated in the ESM study. After the ESM study, I randomly selected four students from each school performance level to be interviewed from all possible students consenting to interviews. One selected student from the middle-performing school did not show up to class on the day of interviews. Table 1 shows the disaggregation of the 75 students who participated in the ESM study and 11 students who participated in the interviews by schools, teachers, blocks, and groups. I randomly divided the students in each class into three groups as described in the next section.

Data Collection

I collected data through journals, interviews, and final study reflections. Prior to administering the ESM, I met with teacher and student participants to review the purpose of the study and the ESM protocols, including semantic scales, and to test signaling methods. Students assigned captains and co-captains to watch for signals. They also collected journal packets, sealed packets, and brought them to the main office. Students viewed their roles as "secret agents" uncovering the classroom factors that directly impacted their attitudes toward mathematics. Their perception of their roles helped students create a sense of empowerment and responsibility for data collection.

ESM Data Collection

The student ESM protocol (see Appendix A) served as the main data collection tool in the study. I administered the ESM at one random time during the beginning, middle, and end of mathematics class over 3 consecutive days during the first, second, and third month of the study at each participating school and class. I divided each class into three groups.

On each day of the study, I randomly assigned each group a different page of the protocol to complete at each signal. Each page corresponded to one dimension of Di Martino and Zan's (2009) framework. I assigned a unique page to each group at each signaling time. This allowed each signaling time to capture responses aligned to each dimension of Di Martino and Zan's framework while being able to generate a complete attitude profile for each student at the end of each class due to covering all three dimensions.

The random assignment introduced novelty and captured students' attention. Moreover, this design empowered students as they understood their unique responses were together contributing to the data collection process. Table 2 illustrates a sample ESM signaling schedule used on one day of the study.

Table 1

ESM Signaling Schedule

	ESM signaling schedule					
	Group 1		Group 2		Group 3	
Time Block	Journal	Time	Journal	Time	Journal	Time
8:10 – 8:15 A.M.	Transition Time					
8:15 – 8:30 A.M.	3	8:29	2	8:28	1	8:24
8:30 – 8:35 A.M.	Transition Time					
8:35 – 8:50 A.M.	1	8:45	3	8:36	2	8:46
8:50 – 8:55 A.M.	Transition Time					
8:55 – 9:10 A.M.	2	9:00	1	9:02	3	9:02
9:10 – 9:15 A.M.	Transition Time					

Note. WTMS M_2D_2 = the researcher's coding for the low-performing school and month 2 and day 2 of the study. ESM = experience sampling method.

I individually coded a total of 171 packets by teacher, month, day, block, and group and organized them to the randomly generated ESM signaling schedules. As illustrated in Table 3, I developed a total of 63 ESM signal schedules and captured 477 random classroom moments over the course of the study. In total, I collected 574 journals. Of these, 50 resulted in incomplete attitude profiles on students as signals were missed for a variety of reasons (e.g., student was in the bathroom or at the nurse). Weather-related events impacted the scheduling of days, and two schools completed eight of the nine scheduled days as interviews had already been scheduled, and it was obvious that saturation of themes had been achieved.

Table 3

ESM Protocols and Random Moments Captured

School	Number of teachers	Number of blocks	Number of ESM protocols per day	Random moments captured per day[a]	Days completing ESM study	Number of ESM Protocols developed	Number of random moments captured
WTMS	2	1	1	9	8	9	144
HTMS	1	4	4	21	9	36	189
MTMS	1	2	2	18	8	18	144
Total						63	477

Note. WTMS, HTMS, MTMS = the researcher's coding for low-, middle-, and high-performing schools, respectively. ESM = experience sampling method.

[a]The number of random moments captured per day was dependent upon the number of classes participating and the number of groups per class or block. For example, HTMS had four blocks participating with two groups in A block, one group in B block, three groups in C block, and one group in D block. Each group received three signals per class, resulting in a total of 21 random moments captured per day. Each journal collected represented three random moments in time, and multiple students were in the same group. The total number of journals collected was dependent upon the total number of study days and the number of students participating per day. Not every student who participated in the study was present for each day of the study (e.g., not in school due to being ill).

Signaling techniques varied by school dependent upon available technology and district technology policies. I presented two options to schools: (a) receive signals through individual cell phones via text messages and (b) receive signals through an online polling software via an iPad or Chromebook. In both cases, I could monitor the progress of the signals. Table 4 details the signaling procedure used at each school.

Table 4

ESM Signaling Methods at Each Participating School

School	ESM Signaling Method
WTMS	▪ Signals sent through an on-line polling website remotely activated by researcher ▪ Students did not interact with website—only used for receiving signals ▪ Each signal activated according to signaling schedule ▪ Signals activated for one minute ▪ 1 Chromebook per group each directed to a different URL ▪ 1 captain and 1 co-captain per group watching for signals ▪ Captain and co-captain signaled classmates
HTMS	▪ Signals sent as pre-programmed text messages through a marketing app ▪ Parents and guardians notified of number generating text messages ▪ Students did not interact with app—only used for receiving signals ▪ Each signal activated according to signaling schedule ▪ Each group had at least one student carrying a cell phone ▪ Students carrying cell phones assigned as co-captains watching for signals ▪ Co-captains signaled classmates
MTMS	▪ Signals sent through an on-line polling website remotely activated by researcher ▪ Each signal activated according to signaling schedules ▪ Signals activated for one minute ▪ 1 iPad per student with each group directed to a different URL

Note. WTMS, HTMS, MTMS = the researcher's coding for low-, middle-, and high-performing schools, respectively. ESM = experience sampling method.

Interviews

Subsequent to the ESM study, I interviewed students and asked about their experiences participating in the ESM study, the stability of their attitudes, and how they felt about doing mathematics. I recorded all interviews and transcribed them verbatim; students provided their unique student identifiers so their interviews could be matched with their data from the ESM study. Appendix B contains the student interview protocol.

Final Reflection

On the final day of the study at each school, I asked students to complete a final reflection. This reflection gave students a last opportunity to capture anything relevant to them regarding how they were thinking and feeling about mathematics and the classroom factors contributing to their attitudes toward mathematics. This reflection also provided another opportunity to test Di Martino and Zan's (2009) framework.

Students provided their unique student identifiers so their reflections could be matched with their ESM data and interviews. The final reflection contained one open question asking students if there was anything additional they wanted me to know about their attitudes toward mathematics or relationships with mathematics.

Data Analysis

I created an Excel database to include all the information from the students' journal packets and associated schools, along with their final reflections. The database contained all 574 journal entries; I coded each entry, except for the 50 incomplete journals mentioned earlier, to 1 of the 8 attitude profiles based upon each student's complete journal protocols. I entered all data into the database.

The first set of questions from the ESM protocol (see Appendix A) resulted in the classification of a student's emotional dimension as positive or negative. The second set of questions resulted in the classification of a student's perceived competence as high or low. The final set of questions resulted in the classification of a student's understanding of mathematics as relational or instrumental. Thus, each completed ESM journal resulted in an attitude profile aligned to Di Martino and Zan's (2009) framework. Students completed all three pages of the ESM journal protocol within a single class period, resulting in one attitude profile per student per class period. I created formulas within the database such that attitude profiles were automatically generated.

I assigned scores of 1, 2, 3, 4, or 5 from the low to high end of the emoticon scale and semantic scale for the emotional dimension and perceived competence dimension, respectively. I coded scores of 4 or 5 as positive. I coded all other scores as negative, including the neutral option. I coded the understanding of mathematics dimension I or R for instrumental (negative) or relational (positive), respectively. I designated positive scores as 1 and negative scores as 0. The neutral option proved useful for three reasons: (a) students perceived nothing was happening in the classroom at the time they received a signal, (b) a new topic had just been introduced and students had not decided how they thought and felt about the topic, and (c) students had not received feedback on work associated with the topic.

Some students unintentionally changed their unique student identifiers. In almost all cases, students could be positively identified from school-level information recorded such as school codes, teacher codes, blocks, or groups. In a few cases, IDs were so different that they were not reliably matched. This is reflected in one aspect of the data analysis, where the total number of students appeared to be 79 rather than 75.

Quantitative Analysis

I used descriptive statistics, frequency analysis, and chi-square tests to address the quantitative research questions focused on the extent to which students' responses to the ESM journal fell within Di Martino and Zan's (2009) framework, the extent to which attitude profiles were stable throughout the study, and the distribution of students within each attitude profile disaggregated by school performance.

Attitude Dimensions Distributions. I created frequency and relative frequency bar graphs to show the distribution of scores for all journal entries within each of the three attitude dimensions. I used box and whisker plots to display median scores and spread, and I used a divergent bar plot to compare the distributions.

Attitude Profiles Distributions. I treated each student's complete attitude profile from each ESM journal protocol as a separate data point, which allowed for the saturation of themes and the descriptions of each attitude profile. As each day of the study resulted in an attitude profile for each student, and students often changed attitude profiles, the collection of entries for a single student might spread about multiple piles. This variety of student profiles aided in analyzing the stability of attitudes. I created virtual piles for each of the eight attitude profiles, and pivot tables were used in Excel to create both frequency and relative frequency bar graphs displaying the number and proportion of entries within each attitude profile, respectively. Subsequently, I disaggregated the data by school performance level (low, middle, high) and used bar graphs and stacked bar graphs to display the information.

Chi-Square Tests. I performed chi-square tests using the disaggregated attitude profiles by school performance level and the chi-square goodness of fit test to look for statistically significant differences between low-, middle-, and high-performing schools within each attitude profile, assuming an equal distribution within the profile. Specifically, I treated each attitude profile as a sample of a population of the attitude profiles to test the null hypothesis that the sample comes from a population with equal proportions within each performance level. A chi-square test of homogeneity assumed each performance level represented a different population to test the null hypothesis that the distribution of attitude profiles is the same for each performance level.

Stability of Attitudes Distributions. I recorded the total number of attitude profiles each student exhibited and used pivot tables in Excel to help create frequency and relative frequency bar graphs to display the information. Subsequently, I disaggregated the number of attitude profiles per student by school performance level and used stacked bar graphs and bar graphs to display the information. I used box and whisker plots to compare the number of attitude changes for all students to those within each performance level.

Qualitative Analysis

The qualitative analysis began when I typed journal entries into the database and transcribed interviews verbatim. I entered data throughout the study when collected. This allowed me to employ Colaizzi's (1978) method, as I read journal entries and interviews multiple times, resulting in the coding of significant phrases and sentences. A holistic coding process produced eight broad coding themes that captured the sense of the entire data set.

I started by analyzing the first two qualitative research questions for each of the eight attitude profiles. I pulled the data for each attitude profile from the Excel database into NVivo. The eight broad categories identified in the holistic coding process served as the initial coding categories or nodes within the coding of the positive-relational-high (PRH) profile.

I chose the PRH profile as the first profile to code since all the dimensions are positive. Once I initially coded the PRH profile, I created subcodes to delineate negative, neutral, and positive attitudes within the broader codes. I then applied these categories across each attitude profile and added additional nodes as necessary.

The Likert scale and semantic scale resulted in natural magnitude coding. As the purpose was to examine real-time classroom factors impacting students' attitudes toward mathematics, the coding process had to be detailed enough to cover nearly all students' statements. Frequency coding allowed for the examination of differences between attitude profiles.

I coded a total of 3,988 statements across eight attitude profiles. Once coding was completed, I completed hierarchy charts to help illustrate similarities and differences across attitude profiles. This coding process, along with detailed notes, resulted in the creation of an overall essence for each theme along with a detailed description of the real-time classroom factors impacting students' attitudes toward mathematics in each attitude profile and the ways in which students described the real-time classroom origins of their emotional relationship with mathematics, their vision of mathematics, and their perceived competence with mathematics.

I followed a similar process with transcripts from students' interviews. I uploaded transcripts to NVivo. The initial themes developed during the holistic coding process and the themes that developed during the coding of each attitude profile served as the foundation for the themes for interviews. I then used structural coding to further develop a set of nodes addressing the last qualitative research question focusing on the ways students described their experiences participating in the study, the stability of their attitudes over time, and the impact of the ESM on their awareness of the real-time classroom factors impacting their attitudes toward mathematics.

Reliability, Validity, and Trustworthiness

The use of the ESM increased the ecological validity and reliability of the students' statements, compared to questionnaires and interviews alone, by capturing many representative moments in time. Moreover, the ESM mitigated typical memory retrieval issues by maintaining the stability of conditions during the encoding and decoding process.

The volume of student journal entries resulted in clear saturation of themes. The detailed, rich descriptions of the essence of each theme and each attitude profile description allowed for transferability (Creswell, 2014). I enhanced reliability by using students' journals and transcribing interviews verbatim. Questions on the ESM journal protocol have face validity with Di Martino and Zan's (2009) framework. Student interviews and final reflections provided an opportunity to use triangulation to corroborate the evidence that resulted in themes and descriptions. Furthermore, the descriptive statistics aided in developing a comprehensive picture of each attitude profile.

I maintained detailed notes during the coding process to ensure consistency of coding themes. Although it was possible for two students to provide different ratings on the emotional or perceived competence dimension for the same reasons, students' explanations made these cases evident. This resulted in detailed rules for coding.

Frequency analysis was necessary to delineate differences across attitude profiles but was not sufficient. I also analyzed statements across each journal protocol. The ESM signaling protocols were developed in such a way as to vary the attitude dimension each group was working on at a particular signal while capturing a complete attitude profile for each student by the end of the class. This design contributed to the validity and reliability of the study. As this was a real-time study, many students were concise with their explanations. However, multiple students captured the same moments in time. This allowed me to accurately piece together fragments of statements for a complete picture of what was happening in the classroom at any particular signaling time while also creating a type of interrater reliability among students. Looking across an individual's journal protocol and within the protocols capturing the same moments in time allowed for an accurate representation of the real-time classroom factors impacting students' attitudes toward mathematics.

Student captains and co-captains collected journal protocols, sealed envelopes, and delivered them to the main office, where they were picked up by me. It was evident that students took the process seriously and felt a sense of empowerment as they often sealed the envelops with phrases such as "Confidential" or "Top Secret" written across the seals.

Results

This mixed methods multiple-case phenomenological study filled a gap in the research by examining the real-time classroom origins, or microvariables, impacting students' attitudes toward mathematics. The study purposely targeted students experiencing their first middle-school mathematics course, as researchers suggest the transition from elementary to middle school is a pivotal time for attitude formation (Mullis et al., 2016; Wilkins & Ma, 2003). Since numerous researchers have indicated attitudes are associated with performance (Aiken, 1976; Choi & Chang, 2011; Di Martino & Zan, 2009; Hattie, 2009; Idil et al., 2016; Ma & Kishor, 1997; Mata et al., 2012; McLeod, 1992; Ruffell et al., 1998; Schofield, 1982; Wilkins & Ma, 2003), I used purposeful and maximum variation sampling to select a low-, middle-, and high-performing middle school in New Hampshire. This sampling technique allowed results to be disaggregated by performance level while looking for similarities within the attitude profiles across the performance levels to develop detailed-rich descriptions of the classroom origins of each attitude profile. The ESM captured 477 representative moments in time in the classroom as students completed journal protocols aligned to Di Martino and Zan's (2009) framework. This allowed for saturation of themes and the analysis of the stability of students' attitudes over time—an issue debated in the literature.

Quantitative Results

Quantitative analysis focused on the distribution of responses within each of the three attitude dimensions, the distribution of students within each attitude profile, attitude profile differences by performance level, and the stability of attitudes over time.

Attitude Dimension Distributions

Table 5 shows the frequency of scores within the emotional dimension and the perceived competence dimension for all journal responses during the study. As demonstrated by the data in Table 5, the distributions across the emotional dimension and perceived competence dimension were nearly identical with about 60% of responses in both dimensions being positive. Students tended to view their emotional states toward mathematics as favorable and generally maintained confidence in their abilities to do mathematics.

Table 5

Emotional and Perceived Competence Dimensions Scores

Attitude dimension	Strongly negative/ not smart (1)	Negative (2)	Neutral (3)	Positive (4)	Strongly positive/smart (5)
Emotional dimension	31	30	162	173	159
Perceived competence dimension	28	49	152	174	173

Note. Emotional dimensions scores were assigned based upon one of five emoticons selected by students and coded from 1 to 5 to represent a strongly negative to strongly positive emotional reaction toward mathematics at the time a signal was administered. Perceived competence dimension scores were based upon one of five blanks on a semantic scale that represented how students were feeling at the time a signal was administered from not smart to smart.

Table 6 shows the relative frequency of 536 journal responses classified as I or R for an instrumental or relational understanding of mathematics at the time a signal was administered. Although the sample should not be considered a random sample from the population, testing the hypothesis that students randomly selected a response equivalent to guessing results in $z = 4.09$ and $p < .001$. These data suggested students in the study were more likely to view mathematics as a series of steps and procedures than interrelated concepts and relationships.

Table 6

Understanding Mathematics Dimension

UMD	Relative Frequency
I	.59
R	.41

Note. UMD = Understanding Mathematics Dimension. I = Instrumental Understanding, R = Relational Understanding.

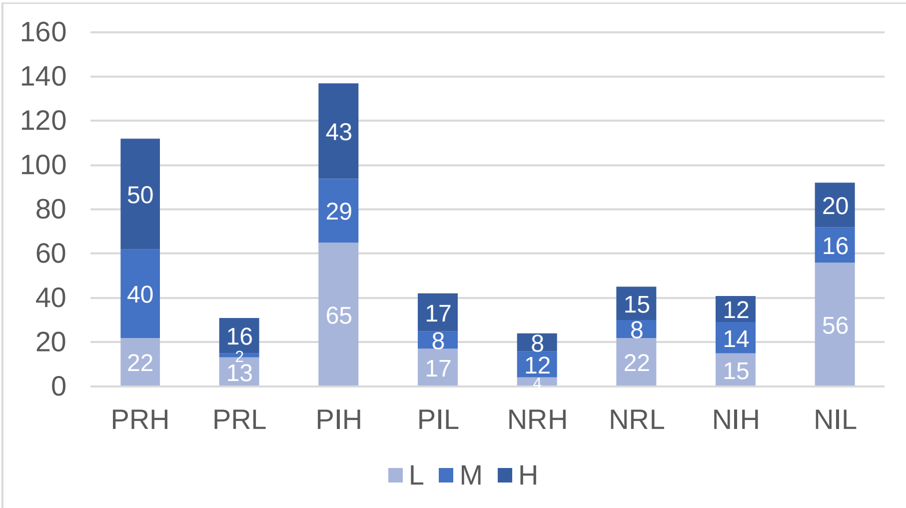
Attitude Profiles Distributions

I collected a total of 574 journals over the course of the study, with 524 resulting in attitude profiles; 50 journals were incomplete for various reasons. Figure 2 shows a stacked bar graph to illustrate the frequency of journal entries classified by attitude profile along with the data disaggregated by school-performance level. Even though the positive-relational-high (PRH), positive-instrumental-high (PIH), and negative-instrumental-low (NIL) profiles are the top three profiles of each performance level, these distributions reveal potential differences across performance levels.

The PRH profile is considered the most desirable profile, and the greatest number of students within that profile are from the high-performing schools. The greatest number of students in the least desirable profile, NIL, come from the low-performing schools. Moreover, the greatest number of students in the positive-instrumental-high (PIH) profile come from the low-performing schools, suggesting perhaps a greater focus needed in those schools on understanding connections across ideas and why mathematical procedures work. These results suggest possible statistically significant differences within attitude profiles across performance levels and possible associations between attitudes and performance.

Figure 2

Attitude Profile Stacked Bar Graph Disaggregated by Performance Level



Note. This figure shows the total journal entries for each attitude profile disaggregated by the school performance level. L = low performing; M = middle performing; H = high performing; PRH = positive-relational-high; PRL = positive-relational-low; PIH = positive-instrumental-high; PIL = positive-instrumental-low; NRH = negative-relational-high; NRL = negative-relational-low; NIH = negative-instrumental-high; NIL = negative-instrumental-low.

Chi-Square Tests

I used a chi-square goodness of fit test to determine if there were any statistically significant differences between performance levels within each attitude profile, assuming a theoretical equal distribution within the profiles. As indicated in Table 7, the proportion of students within the various performance levels was statistically significantly different from an equal distribution within the PRH, PRL, PIH, NRL, and NIL attitude profiles.

Table 7

Chi-Square Goodness of Fit Results

	Observed			Expected				
Profile	L	M	H	L	M	H	$\chi 2$	*p*
PRH	22	40	50	36.96 (0.33)	36.96 (0.33)	36.96 (0.33)	10.91	.004
PRL	13	2	16	10.23 (0.33)	10.23 (0.33)	10.23 (0.33)	10.63	.005
PIH	65	29	43	45.21 (0.33)	45.21 (0.33)	45.21 (0.33)	14.58	<.001
PIL	17	8	17	13.86 (0.33)	13.86 (0.33)	13.86 (0.33)	3.90	.142
NRH	4	12	8	7.92 (0.33)	7.92 (0.33)	7.92 (0.33)	4.04	.132
NRL	22	8	15	14.85 (0.33)	14.85 (0.33)	14.85 (0.33)	6.60	.037
NIH	15	14	12	13.53 (0.33)	13.53 (0.33)	13.53 (0.33)	0.35	.840
NIL	56	16	20	30.36 (0.33)	30.36 (0.33)	30.36 (0.33)	31.98	<.001

Note. Numbers in parentheses, (), are expected proportions. Profile = Attitude Profile; L = low performing; M = middle performing; H = high performing; PRH = positive-relational-high; PRL = positive-relational-low; PIH = positive-instrumental-high; PIL = positive-instrumental-low; NRH = negative-relational-high; NRL = negative-relational-low; NIH = negative-instrumental-high; NIL = negative-instrumental-low.

Students from the low-performing school seem overrepresented in the PIH and NIL categories. Students from the high-performing school seem overrepresented in the PRH category. Moreover, considering the sample of all journal entries with an instrumental understanding of mathematics as a subset of the population of all students with an instrumental understanding of mathematics, a chi-square goodness of fit test revealed that the distribution of instrumental understanding profiles was not the same across performance levels, $\chi^2(3, N = 317) = 39.32, p < .001$. Similar results hold for the relational understanding category, $\chi^2(3, N = 219) = 6.00, p = .050$.

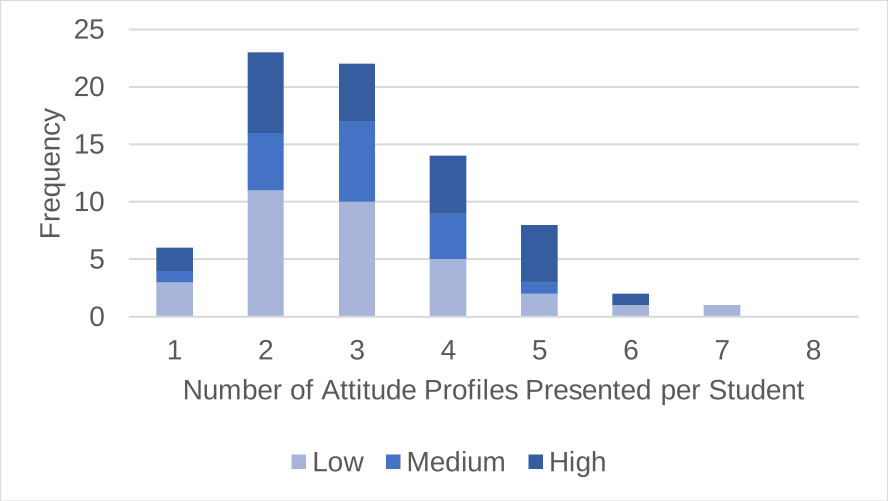
Considering each performance level as a subset of a different population of low-, middle, and high-performing schools, a chi-square test of homogeneity indicated the distribution of attitude profiles is not the same for each performance level, $\chi^2(14, N = 524) = 60.18, p < .001$.

Stability of Attitudes Distributions

As students submitted multiple ESM journals, I recorded the total number of attitude changes for each student. Figure 3 shows the frequency of attitude changes and disaggregated data by performance level.

Figure 3

Attitude Profile Changes Stacked Bar Graph Disaggregated by School-Performance Level



Note. This figure shows the number of attitude profile changes disaggregated by school performance level.

Students tended to exhibit between two and four attitude changes, with about 8% of students not changing their attitudes and approximately 14% of students presenting five or more attitude profiles. These results suggest students can and do change their attitudes toward mathematics and attitude profile changes do not appear to differ by performance level.

Qualitative Results

I have presented the qualitative results in the order they were described in the data analysis section: (a) eight broad coding themes that resulted from the analysis of all students' statements across all journals, (b) descriptions of the essence of the experience for each of the eight attitude profiles, and (c) a description of the essence of the experience based upon students' interviews addressing the third qualitative research question. I used textual and structural descriptions as students described what was happening in the mathematics classroom at the time a signal was administered, what they and their teacher were doing at that time, and how they were thinking and feeling about mathematics at that time.

Emergent Themes

Eight initial themes emerged from a holistic coding process of all students' statements: (1) technology and games, (2) novelty, (3) difficulty level, (4) success perception, (5) self-perception, (6) timely feedback, (7) student choice, and (8) speed. My analysis of these eight themes revealed several key observations: (a) the success or failure students experienced was linked to their self-perceptions as learners of mathematics, to their emotional states, and to their perceived competency; (b) students' perceptions of the difficulty of a task was connected to their success perceptions; (c) the mathematics classes in the study were highly structured, and the use of technology (e.g., Kahoot, Cool Math Games, Banazi) provided novelty to that structure; and (d) the 477 random moments in time captured rarely revealed moments when students were explaining their thinking or talking about mathematics. Detailed statements from students supporting these conclusions are provided in Andrusiak (2018).

Each theme provided insight into the entire data set and was subsequently expanded for the coding of each attitude profile. For example, even though student choice did not emerge from frequency coding, it was worth capturing, as marginalized voices are often overlooked. M10316 was a student in the study who exhibited the least desirable attitude profile, negative-instrumental-low (NIL), and only changed that profile once during the duration of the study. This student was one of the most articulate students in the study but often described feeling dumb or stupid despite capturing some of the most detailed descriptions of the mathematical content being covered at the time of a signal. M10316 provided deep insights into ways to shape attitudes toward desirable profiles through student choice when the student justified her attitude profile by saying, "In math, we don't really get to choose anything. [The teacher] just tells us what to do and doesn't give us a choice." The development of this theme of choice resulted in the addition of a student- and teacher-directed theme in the analysis of the attitude profiles.

Real-Time Origins of Attitude Profiles

I coded the positive-relational-high (PRH) attitude profile first, as all dimensions were positive. Subsequently, I expanded the themes that emerged from the PRH profile as necessary and added subcodes delineating negative, neutral, and positive attitudes within the broader codes. This allowed for the coding of almost all students' statements. While such a systematic approach is not normally taken in qualitative research, it was ideal in this study to reveal the real-time origins of each attitude profile and to capture differences across profiles. Although frequency coding played an important role, I also examined statements across each journal protocol and within the context of the real-time moments captured as multiple students captured the same moment in time.

I developed a table, showing the number of references coded to each node and subnode, to support each attitude profile description, a hierarchy chart to convey the relative frequency of references coded to each node and subnode through an area model, and a table of students' statements supporting the overall essence of the real-time classroom factors contributing to each attitude profile. All three of these elements are presented for the PRH profile and subsequently only the table of students' statements are presented in support of each profile description. See Andrusiak (2018) for further details.

As rich descriptions can lead to transferability in qualitative studies (Creswell, 2013), I wrote each attitude profile description mostly in present tense. Using present tense aids in capturing how students in each profile think and feel about mathematics and the classroom activities that contribute to each attitude profile. Past tense is used when referring to the number of references made.

Positive-Relational-High (PRH) Profile. Table 8 shows the number of nodes, subnodes, and references coded in the PRH profile.

Table 8

PRH Nodes, Subnodes, and References

Node	Number of references
Complexity	56
Challenged	10
Confused	6
Easy	29
Not challenged	7
Other	4
Connections	8
Content description	89
Corrections	15
Enjoyment	23
Negative	2
Neutral	1
Positive	20
Exit tickets	2
Group work	3
Homework	6
Journals	1
Multiple methods	3
Notes	22
Problem-solving strategies	1
Questioning teacher	1
Real-world connections	26
Review	3
Rules and steps	4
Self-perception as learner	125
Negative	2
Neutral	11
Positive	112
Speed	4
Other	4
Too fast	0
Too slow	0
Student directed	11
Success perception	90
Negative	0
Neutral	5
Positive	85

Node	Number of references
Teacher directed	25
Negative perception	0
Positive perception	6
Teacher helped	15
Teacher perception	12
Negative	0
Positive	12
Technology & games	90
Tests and quizzes	67
Test prep	21
Warm-ups	25
Working problems	44

As Andrusiak described (2018):

Students in the PRH attitude profile experience success, have positive self-perceptions as learners of mathematics, and demonstrate confidence in learning new concepts. These students are more likely to describe mathematics as being easy than challenging and they often express the desire to be challenged. Students in the PRH profile often give content descriptions of the material they are studying and have positive views of their teachers and their teachers' abilities to support their learning. These students enjoy learning new material and cite real-world connections and working with technology frequently. They do not describe the pace as being too fast. Students cited teacher-directed activities more than double student-directed activities and it is rare that signals captured moments where students described talking about mathematics. As these students have a relational understanding of mathematics, they do not often describe mathematics as a set of rules or steps. Moreover, these students describe making connections across ideas and find mathematics enjoyable. Some students, such as M10717 seem to indicate that they have an intrinsic relational understanding of mathematics as evident by statements such as, "She (the teacher) hasn't really done anything to make me understand math in that way that's just what I think." Technology and games, followed by test prep and quizzes, working problems, making real-world connections, and warm-ups dominate classroom activities. Low level activities are journals, exit tickets, questioning the teacher, and group work. (p. 123)

Table 9 shows selected student statements in support of the PRH profile description.

Table 9

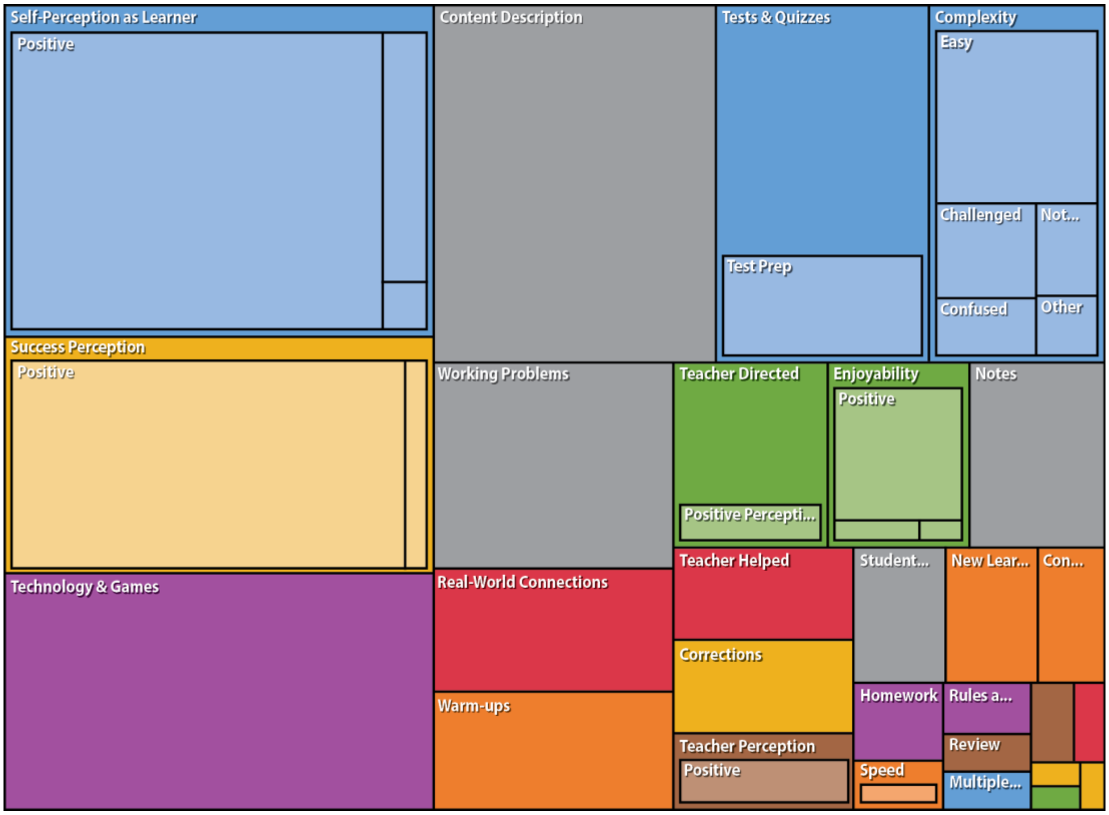
Select Students' Statements in Support of PRH Profile Description

Student	Statements
M00813	• I feel good so far because I understand everything so far.
D10516	• I feel I understand mathematics very well and am very good at it.
R51114	• I'm somewhat confused but I think I can figure it out.
F00105	• I am doing well on Khan an [*sic*] I'm being productive
L00515	• I'm getting all the answers fairly easily.
M10717	• I do great in math. I love doing math and reading about math. I'm reading "understanding Physics" by Isaac Asimov. I think I need a greater challenge because math class now is too easy.
E20619	• We are learning "Net" which is when a three dimensional shape is layed [*sic*] flat.
A20513	• I never liked math until sixth grade until I met [the teacher]. He brings joy to the classroom.
A40513	• He is helping us with knowing why an answer is an answer.
M20917	• I really like hard problems and [it] is fun for me to learn new math things
M10818	• We saw how much water was in our body.
F00115	• I have been playing Kahoot and doing well. This made me feel smart.
C10908	• I think this because different ideas make procedures work.
R51114	• Because math is basically strategy like a game you have to figure out. Everything in math is connected
M00215	• I am sort of having fun with this woo hoo!!!

Figure 4 shows the related hierarchy chart.

Figure 4

PRH Hierarchy Chart



Note. This figure shows a geometrical representation of the relative frequency of the number of references coded at each node and subnode in the PRH profile.

Positive-Relational-Low (PRL) Profile. As described in Andrusiak (2018):

> Students in the PRL attitude profile tend to have positive self-perceptions as mathematics learners and express a positive enjoyment of mathematics. However, these perceptions often were coded neutral due to the successes students' experienced. Out of the 31 journal protocols coded to the PRL category, only six of them fall into the category due to students selecting a one or two on the perceived competence scale as 25 of these journals contained a neutral rating in this category. PRL students often give content descriptions of what is happening in class and frequently work with real-world

connections which they view positively. They are more likely to cite teacher-directed activities than student-directed activities and are just as likely to have positive impressions as neutral impressions of teacher-directed activities. PRL students never express positive impressions of their teachers and never cite receiving help from their teachers. They most often cite technology and games, real-world connections, test and quizzes and test prep, working problems, and note taking as class activities. These students tend to have a positive outlook on technology and games but choose neutral categories if not experiencing success. They have a slightly more negative view of test prep than working on actual test and quizzes. PRL students tend to choose neutral or positive ratings for their perceived competence when working problems or taking notes. They rarely cite journals or warm-ups as activities. (pp. 127–128)

Table 10 shows selected student statements in support of the PRH profile description.

Table 10

Select Students' Statements in Support of PRL Profile Description

Student	Statements
E10114	▪ I feel good as a learner because I get it.
M10213	▪ Because I ♡ math.
E20619	▪ I feel smart like I know some stuff but I also don't know stuff and I don't feel super smart I just feel smart.
R00913	▪ Pretty good but I think I could work a little bit harder in some places.
S31005	▪ Going over examples of solving equations by multiplying/dividing.
K00616	▪ I am learning how to spend money for my life.
M20113	▪ Just doing the test no teacher for help yet.
S31005	▪ Because the teacher is explaining things more. [Note: It is plausible that this student has a negative impression of the teacher's explanation or that the student has low perceived competence since students in general did not understand the concept or experience success and the concept needed to be explained again.]

Student	Statements
C10908	• We are watching a video about statistics on Khan Academy. [Note: This statement was followed by the student saying, "I'm excited to learn." These statements were provided by the student as explanations of choosing a 5 on the emotional dimension.]
J10403	• For the pretest I got a 40% and I'm not feeling that good about it.
S10115	▪ Doing [g]ood on test.
H01216	▪ We are doing 3.4 exercises in the hard cover book. [Note: This statement paired with a neutral score on the perceived competence dimension.]

Positive-Instrumental-High (PIH) Profile. Table 11 shows selected student statements in support of the PIH profile description.

Table 11

Select Students' Statements in Support of PIH Profile Description

Student	Statements
D01015	▪ I feel good and able to complete the problems and apply logic to solve problems.
I10815	▪ I'm getting it and I'm getting them right.
C10908	▪ I am feeling pretty smart about linear equations (what we are learning about) because during the math homework I am getting almost all of the problems correct.
D01015	▪ I enjoy mathematics very much and hope to learn even more in the future.
R11216	▪ I want math to be more challenging. We're doing things from like 2 years ago.
R20613	▪ Its [*sic*] really easy what we are doing in class.
R20415	▪ Bored.
M11213	▪ I don't think so because I like math. I just think it can be boring, which has nothing to do with mathematics. So no I don't. [This was M11213's final reflection and the students' modal attitude profile was PIH.]
L10614	▪ We're going over how to put inequalities that are in 2 word sentences into 1 equation.
R20114	▪ He explained it very clearly and answered all of our questions.
I10815	▪ You can't go from a fraction to a percent you have to make a fraction a decimal. If you break the rules it won't work.
A00216	▪ I still think if you don't follow the assigned rules you will get a wrong answer!

Student		Statements
L01214	▪	I have passed in my test and I think that with all of the practice that I did good on it.
A00615	▪	I have continued the Banazi scenarios. It is fun! I am having fun with the real life scenarios.

As Andrusiak (2018) described:

Students in the PIH attitude profile tend to experience success, have positive self-perceptions as learners of mathematics, and describe mathematics as enjoyable. Similar to students in the PRH profile, these students express an interest in being challenged. Students' statements in this profile were much more likely to be coded to the easy category of the difficulty/complexity node than students in the PRH profile. It is also worth noting that no statements in the PRH profile mentioned being bored or that mathematics was boring; however, while not many, some statements in the PIH category are coded to this sub-node. Students in the PIH profile often give content descriptions of the material they are studying. In comparison to students in the PRH profile, PIH students are less likely to mention their perceptions of their teachers or cite their teachers helping them. However, when they do, they have positive views of their teachers and their abilities to support their learning. As these students have an instrumental understanding of mathematics, they often describe mathematics as a set of rules or steps. These descriptions often describe specific processes being applied in problems. Students in this profile never specifically mentioned making connections across ideas. The two dominating classroom activities are test and quizzes, including test prep, and working problems. Students have positive outlooks on both activities and rarely cite anything negative associated with testing or working problems. These activities are followed by, in terms of frequency of students' statements, technology use, working on warm-ups, and real-world applications. This is a slightly different order of activities in comparison to the PRH profile. Low level activities include reviewing material, homework, and group work. (pp. 133–134)

Positive-Instrumental-Low (PIL) Profile. Table 12 shows selected student statements in support of the PIL profile description.

Table 12

Select Students' Statements in Support of PIL Profile Description

Student	Statements
S01007	▪ I can do math.
K01118	▪ I feel ok but I don't think I got the answers correct.
A00216	▪ I got the correct answer on a surface area math problem and I didn't last time so that was exciting!
M30917	▪ It seems like it is easy.
J10214	▪ Ok. What we are about to do is kind of confusing.
M00813	▪ I don't really fully understand.
A00213	▪ I don't understand what we do sometimes.
M20619	▪ You can only do math following rules.
M11213	▪ We were adding and subtracting positive and negative numbers. There are rules, to add and subtract them, like if they are different you have to add.
M20619	▪ I enjoy doing math mall.
A00213	▪ She doesn't explain things good enough and when we learn something new she jumps into the other half a day later and doesn't give much time to learn it.
M30113	▪ Feeling good and positive in class today and my teacher will help me today.
A00216	▪ I don't fully understand how checking, and balances works. I understand debt and some stuff though.

As Andrusiak (2018) described:

Students in the PIL attitude profile tend to have positive self-perceptions as mathematics learners even though they tend to rate their perceived competence as neutral or low. Only about 26% of the 42 students' journals, classified to this attitude profile, indicated a true negative rating. The remainder of journals indicated a neutral option. PIL students are about equally likely to give content descriptions as students in the PRH, PRL, and PIH profiles, where about 10% of the total statements coded had specific content references. Students in this category, are equally likely to describe the content as easy, confusing, or hard. PIL students recognize that they are getting material correct, but sometimes describe that they do not understand what they are doing and cite the material as confusing. As students in the PIL category have an instrumental understanding of mathematics, they often cite having to follow the rules. PIL students tend to be tentative about feeling positive as mathematics learners due to the success being experienced. N00614 seems to exemplify this profile. This student selected a positive emotional rating and described going into google classroom to play a mathematics game. At the subsequent signal, the student justified a negative perceived competency selection by stating, "I am still playing the game but it got hard." However, the student later went on to say, "Playing the math game with money made me understand what I picked up there. I feel good but sometimes I don't get it." C10908 provided a similar example. At the first signal, this student selected a positive emotional reaction to mathematics and justified the rating by stating, "Excited to start test and I feel ready." However, once the test started, the student described being confused on the test and selected a neutral score for perceived competence. However, by the end of the class, the student referred to feeling good "because I understand what's on the test." Tests and quizzes, technology, and working problems dominate the classroom activities. The distributions of negative, neutral, and positive reactions to technology and games

> and working problems are fairly uniform. Students in the PIL category are as likely to describe tests and quizzes in a negative or neutral way as in a positive way. They do not tend to mention their perceptions of their teachers very often and when they do, they exhibit the same type of pattern as just described by having split reactions. Real-world connections are not often referenced, and when they are, students tend to exhibit mixed reactions. Journals, homework, and group work are rarely if ever mentioned. (pp. 135–137)

Negative-Relational-High (NRH) Profile. Table 13 shows selected student statements in support of the NRH profile description. Less than 5% of all journals were coded to this category, and two thirds of them were due to a neutral selection on the emotional dimension.

Table 13

Select Students' Statements in Support of NRH Profile Description

Student	Statements
E10114	▪ I feel good as a learner because I get it.
F00115	▪ I got most questions right and the ones I got wrong I fixed without much trouble.
M21016	▪ Feel like I am being held back from new thing[s] in math.
M21016	▪ I don't like test[s] but I don't hate them it is a bit boring.
M00118	▪ Bored.
S60915	▪ We are doing our summative.
E10114	▪ I chose this face because all we do is stuff in our book which get boring.
R00614	▪ <u>Because I feel good about the sheet of work</u>. [This statement was underlined by the student for emphasis.]
M10116	▪ We got on to Banzai. [This statement was provided as an explanation for selecting a high perceived competence score.]

Student	Statements
E10114	▪ We are working in our group and everyone is doing their part to help solve answers. [Note: This response was provided at a different signal in the same class period after the response referenced above where the student had a negative emotional state due to book work being considered boring.]
M10213	▪ I feel good because we can work together and it's kind of like a project.

As Andrusiak (2018) described:

Students in the NRH attitude profile tend to see themselves as being successful with mathematics and have positive perceptions about their learning. In 782 coded statements in the PRH category, students never mentioned that mathematics was boring or that they were bored in mathematics class. About 5% of the coded statements in the NRH category made such a reference. While this might be considered a small percentage of the overall statements, in comparison to their PRH peers, NRH students rarely mention mathematics as enjoyable which was the dominate perception of mathematics in the enjoyment node in the PRH profile. Slightly over 11% of the coded statements in the PRH profile included content descriptions, whereas, slightly less than 8% of the coded statements in the NRH profile contained content descriptions. Test and quizzes by far dominate the classroom activities referenced, followed by working problems and technology and games. NRH students rarely if ever mentioned their perceptions of their teachers or receiving help from teachers. Real-world connections were never associated with a negative experience when mentioned. While these students rarely mention group work, when they do, they have a positive perception. (p. 139)

Negative-Relational-Low (NRL) Profile. Table 14 shows selected student statements in support of the NRL profile description. As described in Andrusiak (2018):

Students in the NRL attitude profile tend to have positive self-perceptions as mathematics learners even though they tend to have negative success perceptions. Students in the NRL profile do experience some success, just not as often as they experience failure. NRL students overwhelmingly describe mathematics as boring and tend to be less likely to provide content descriptions than their peers in attitude profiles with positive emotional states. NRL students never mentioned their teachers helping them, and when they refer to their perceptions of their teachers or teacher directed activities they are associated with negative responses. Test and quizzes and working problems dominate the classroom activities, and these students rarely have a positive perception of these activities. Out of 81 total references to these activities, only one was coded as positive. Technology is the next referenced activity; however, the number of references is less than half of the references to test and quizzes and some of these references simply state that mathematics is boring and that more technology should be integrated into the classroom. Lower experienced activities were notes, real-world learning, and warm-ups. There were no positive references to taking notes or working on warm-ups. Rarely or ever mentioned was time working on homework, journals, or review. When describing their relational understanding of mathematics, students tended to cite always thinking that way or struggled to explain why they held that belief. (pp. 141–142)

Table 14

Select Students' Statements in Support of NRL Profile Description

Student	Statements
K01118	▪ I feel good because I know a little of this.
M10213	▪ I feel good.
NM30816	▪ The summative really stumped me and I feel like I got my first NYP. [Note: NYP refers to not yet proficient.]
L21214	▪ It feel[s] okay I guess. Math has always been my subject even if I'm not great at it.
H1404	▪ I feel like a dumb potato.
E10419	▪ Math has been boring and I don't understand our teacher.
M10316	▪ Teacher is talking about unit rates. I want to go home so badly. I'm so bored. It's 1:25 ugh. I have to wait almost an hour for the bell to ring. We're going over the warm-up. I didn't know how to do it though.
S10115	▪ I feel great as a learner but math can get boring.
L21214	▪ Once again testing. [Note: This response was given as a rationale for the selection of a low perceived competence score.]
J51015	▪ Confused and bored. We need more math games to play.
E10419	▪ We are writing boring notes.
NM30816	▪ Because its [*sic*] how I think. [Note: This is in reference to selecting a relational understanding of mathematics.]

Negative-Instrumental-High (NIH) Profile. Table 15 shows selected student statements in support of the NIH profile description.

Table 15

Select Students' Statements in Support of NIH Profile Description

Student	Statements
J51015	▪ I [am] feeling really good about math but I think we should add [m]ore math games so math is more fun.
R11216	▪ I didn't really get how to solve the problems but now I understand the rules I have to follow.
M11016	▪ I didn't know anything about it unlike everyone else but I still solved it on the board. [The student added a smiley face at the end of the statement.]
A00213	▪ What we are doing is really easy.
M11213	▪ Because taking notes is boring and I kinda already know how to do this.
J31015	▪ Math class is getting more boring.
J10214	▪ He (the teacher) was just talking so it was kind of Boring.
M20716	▪ I got 80–100 on the last 3 tests.
M20716	▪ I do not like tests. [Note: This response was given in the same lesson as the previous quote by the same student explaining a negative emotional reaction with a high perceived competence.]
N10914	▪ The tests are kinda boring.
N00614	▪ I feel good about that because we are doing an activity called Banazi and it's hard but fun.

As Andrusiak (2018) described:

Students in the NIH attitude profile tend to have positive self-perceptions as learners and often express experiencing success with their work. They are more likely to describe the material as easy in comparison to challenging or hard. They tend to have negative emotional reactions to mathematics due to feeling that mathematics is boring. They never make reference to working in groups and seldom reference independent activities. While NIH students do tend to refer to teacher directed activities, they rarely ever mention their perceptions of their teachers or teachers helping them. NIH students were the least likely out of all the attitude profiles to provide content descriptions with only 6%

> of the coded references in this category referring to content. Whereas, about 12% of the total coded references referred to content in the PIH category. The PIH category had the highest proportion of references referring to content. Test and quizzes are the dominating activities and students in the NIH category are about as likely to have negative as positive reactions to these activities. Students often demonstrate high perceived competence due to experiencing success with tests and quizzes, but often describe not liking them. The second most referenced category is technology and games, but the number of references to tests and quizzes is nearly double the references to technology and games. Students have an overall positive experience with technology and games. This is followed by working problems and taking notes. These are activities where students express mixed reactions. There are few references to real-world connections or warm-ups, and almost no references to homework or journals. (p. 144)

Negative-Instrumental-High (NIL) Profile. Table 16 shows selected student statements in support of the NIL profile description. As Andrusiak (2018) described:

> Students in the NIL attitude profile tend to have self-perceptions as mathematics learners that are more neutral and positive than negative, but their success perceptions are overwhelmingly negative. Students in the NIL category tend to describe mathematics as boring, confusing, and sometimes too fast. They never mention working in groups and rarely mention receiving help from their teachers. They hold negative perceptions of their teachers, and teacher-directed activities are perceived negatively. This is the modal category of M10316 mentioned earlier in the student choice theme. Recall that M10316 articulated how students have no choices in their learning. Test and quizzes dominate the classroom activities, and no references were coded to a positive experience with these activities. The next referenced activities were warm-ups and working problems. Both categories received nearly equal references and out of 92 total references only one

is positive. These negative references are largely due to the lack of success with these activities. Technology and taking notes followed in the number of references with notes receiving no positive references. Real-world learning, homework, and journals are rarely mentioned. NIL students do not seem to be able to make connections to what they are learning to the real-world. (pp. 146–147)

Table 16

Select Students' Statements in Support of NIL Profile Description

Student	Statements
A00516	I feel okay about math and that I am horrible at math but still enjoy the class.
A00213	I feel ok but what we are working on is so confusing that I don't feel that smart.
J00115	Feeling good because we get to use our iPads to help us with our math.
T10507	I have no clue how to do this even though we've been doing it for a while. It's probably because it gets really boring so I space off. I'm most likely gonna fail everything about this.
T10507	It's really boring, confusing and I don't feel good so. I don't understand why we need to learn this stuff cause it's not like we will have to use it in the "real world."
M10306	We're doing our warmup. I'm solving this question: $6 + h > 9$. Ugh I hate math this is so boring. Yesterday right after iready testing (math) the teacher made us do more work (math).
N10914	I feel like we move on to fast and I can't keep up.
E10419	I don't understand it that well because the teacher is confusing.
A00213	I don't understand at all. The problems are one way but she did it the other.
R00913	Because I don't really understand how she is teaching me.
M11016	We have a summative to work on Nuf said. [This was an explanation for a negative emotional dimension score.]
N10914	I don't think it's fun to do endless questions.
A00213	Because word problems frustrate me and I don't get what we had to do.

Student Interviews

After the ESM study, I interviewed students and asked them to describe their experiences participating in the study, the stability of their attitudes over time, and the effect of the ESM on their awareness of the classroom factors impacting their attitudes. Students expressed positive sentiments regarding participating in the study and valued expressing their opinions about mathematics classes in a way that could impact future courses. Students provided insights into the classroom factors impacting their attitudes that had fidelity with the attitude profile descriptions and ESM analysis. Participating in the study did not necessarily heighten students' awareness of the factors impacting their attitudes, but participation enhanced students' abilities to self-reflect on what was happening in the mathematics classroom by heightening their focus in the classroom as they waited for signals.

Summary

My quantitative results suggested students' responses fit within Di Martino and Zan's (2009) framework and were consistent with their findings that attitudes can and do change over time. Students mostly maintained positive emotional states toward mathematics and believed they could be successful doing mathematics. Distributions of attitude profiles and the proportion of students within certain attitude profiles differed across performance levels. Students from the high-performing school were overrepresented in the most desirable attitude profile, PRH, and students from the lowest performing school were overrepresented in the least desirable profile, NIL, and the PIH profile. The number of attitude profile changes did not appear to differ by performance levels.

Qualitative results revealed students in all eight attitude profiles tended to exhibit positive self-perceptions as learners of mathematics and their perceived competency was highly linked to the successes or failures they experienced. Tests and quizzes were the dominant classroom activity among all four attitude profiles containing a negative emotional dimension. Analysis revealed differences in various classroom activities and their impact on students' attitudes, such as (a) the use of technology and games, (b) real-world connections, (c) quizzes and tests, (d) homework, (e) working problems, (f) students' perceptions of their teachers, (g) the enjoyment of mathematics, (h) and the difficulty of the material. Interviews helped me triangulate the data and revealed students developed their abilities to self-reflect on their own understanding of mathematics and what was happening in the classroom at the time a signal was administered.

Discussion and Conclusion

I used the ESM in this mixed-methods, multiple-case phenomenological study to reveal insights into the real-time classroom factors impacting students' attitudes toward mathematics. Teachers can use the rich descriptions of the attitude profiles when developing intervention strategies for students and when working on curriculum development and designing classroom instruction, pedagogy, and assessment. Both the quantitative and qualitative results provide insights into how students think and feel about doing mathematics as they transition from elementary to middle school.

Quantitative Results

The ESM journal protocol has face validity with Di Martino and Zan's (2009) framework and the open-ended questions, along with the final reflection, allowed students to elaborate on the classroom factors impacting how they were thinking and feeling about mathematics. In Di Martino and Zan's study, only 2.1% of essays failed to refer to at least 1 of the 3 dimensions of their framework. Consistent with those findings, only one journal out of 574 in this study did not clearly fall within the framework.

Only 8% of students in this study maintained a consistent attitude profile. McLeod (1992) found attitudes tend to be stable over time. Wilkins and Ma (2003) found students' notions of mathematics changed little from the beliefs they held in seventh grade to secondary school. Successive TIMSS studies since 1995 show nearly double the percentage of students reporting disliking doing mathematics in eighth grade compared to fourth grade. Results of this study showed a greater percentage of students presenting five or more attitude profiles than no profile changes. This supports evidence that the transition from elementary school to middle school is crucial to the formation of mathematical attitudes. Consistent with Di Martino and Zan's (2009) findings that attitudes can and do change over time, this is encouraging news for educators as they can use the results from the qualitative analysis to shape classrooms in ways that help shift students' attitudes toward more desirable profiles.

Students mostly maintained positive emotional reactions toward mathematics and had positive perceptions of themselves as learners of mathematics. The two highest occurring attitude profiles presented in the study were the positive-relational-high (PRH) and positive-instrumental-high (PIH) profile. However, the next most frequently occurring profile was the least desirable profile, negative-instrumental-low (NIL). This last result suggests a shift in attitudes could be occurring at middle school.

Consistent with beliefs and findings related to associations between attitudes and performance, this study revealed students from the high performing school were overrepresented in the most desirable attitude profile, PRH, whereas students from the low-performing school were overrepresented in the least desirable profile, NIL. However, nearly the same number of students exhibited a PIH profile as a NIL profile. The PIH profile could be considered a single step away from the most desirable profile, PRH. Students exhibiting an instrumental understanding of mathematics often cited their teachers as teaching mathematics as a series of steps and procedures for solving problems. Moving from the PIH to the PRH profile could be a matter of exposure. Teachers need to provide greater opportunities for students to make connections both within and across ideas in mathematics while focusing on the conceptual underpinnings and problem solving. The qualitative results reveal greater insights into how to transition students from less desirable attitude profiles to more desirable profiles.

Qualitative Results

The eight emergent themes provide insight into how teachers can shape classrooms in ways that promote positive attitudes toward mathematics. In particular, it is important for teachers to focus on (a) the use of technology and games, (b) novelty, (c) students' perceptions of success, (d) students’ self-perceptions as learners, (e) timely feedback, and (f) student choice. The attitude profile descriptions delineate clear differences among various profiles.

Technology and Games

The use of technology can either enhance or inhibit student learning. Students’ reliance on technology can negatively impact their creativity and critical thinking and process skills (Sousa, 2017). However, a meta-analysis of the integration of computer applications in K–12 classrooms showed a greater impact on mathematics achievement than programs without computer applications (Sousa, 2016). Thus, technology needs to be used in meaningful ways within safe and nurturing learning environments where students feel respected, valued, and empowered.

Kolb’s (2015) triple E framework outlined three essential components of technology integration for meeting student learning outcomes and objectives: (a) engagement, (b) enhancement, and (c) extension. Technology needs to not only capture students’ attention but also engage them in the content while scaffolding learning in ways not easily captured in traditional methods and extending learning to support real-world connections (Kolb, 2015).

Novelty

The volume of random moments in time captured in this study made it evident that the classrooms in the study tended to follow the same daily routines. The vast number of students who fell within undesirable attitude profiles cited mathematics as boring. Introducing novelty in the classroom through a variety of activities such as technology integration, games, music, movement, humor, and encouraging student choice can make teaching and learning more interesting (Sousa, 2016).

Self-Perceptions and Success Perceptions

As justification for rankings on the various attitude dimensions, students often cited their perceptions of themselves as mathematical learners and the success or failures they encountered. These results are also consistent with Di Martino and Zan’s (2009) findings where low perceived competence was reinforced by repeated failures. Teachers need to find ways to ensure that students experience success every day in the classroom.

Overemphasis of large-scale assessment, despite evidence these assessments result in educational improvements (Ravitch, 2016), has resulted in an overreliance on traditional exams and quizzes in the classroom. Exams and quizzes dominated the classroom activities among all four attitude profiles containing a negative emotional dimension. Andrusiak et al. (2020) detailed core principles for how educators can transform education through student-centered learning that ensures that each student is valued in every school and in every classroom while recognizing that success looks different for each student. Success is intimately connected to timely feedback and student choice.

Timely Feedback

The timely feedback theme mostly presented with summative assessments. While not dominant, the theme was powerful, as students were noticeably tentative about their attitudes toward mathematics when they were awaiting feedback. Lack of timely feedback inhibited students' abilities to move forward in their learning. Formative assessments provide an opportunity to provide timely feedback. The privilege of feeling success is often reserved only for the best students as feedback is often delayed, particularly on summative assessments (Christensen et al., 2011). Moreover, the added pressure of timed tests can cause anxiety by releasing cortisol into the bloodstream and causing the frontal lobe to disengage in learning (Sousa, 2017). Andrusiak et al. (2020) discussed ways to progressively give more authority and responsibility to students, including suggestions for reforming assessment by creating student-centered open projects.

Student Choice

Students often cited real-world learning as a key classroom factor impacting their attitudes in the most desirable attitude profile, PRH. Working problems was a common activity cited in the least desirable attitude profile, PIH. Providing students choices in their assignments can result in authentic learning opportunities while increasing the depth of knowledge and complexity of tasks in comparison to traditional problems while increasing enjoyment and valuing that all students learn differently.

Students who have choices in assignments experience greater proficiency and satisfaction with their work while producing higher quality work in comparison to students who have less autonomy (Sousa, 2016). Preble and Gordon (2011) found students in schools with negative climates almost never have the opportunity to make choices on assignments or how they learn. Every school improvement initiative is subject to fail if there are issues with school climate and culture (Sarason,1990).

Student choice also increases student voice. Students interviewed in this study valued the opportunity to express how they thought and felt about mathematics. For example, when I asked Joe, or R20415, what he liked about participating in the study he stated, "Um, you got to voice your opinion on what was going on and how math class made you feel." The signaling process provided moments where students could self-reflect on their understanding of mathematics while empowering them to be part of the change process. Elizabeth, or E20619, summarized this idea when she stated, "It was like . . . it kinda felt cool [to participate in the study] . . . that we get to like try and help change the math class and like make it kinda how we want to learn and not the way the teachers [want us to learn]."

Middle school students value their schooling most when their voices are heard by their teachers (Mitra, 2009). This study demonstrated a dearth of classroom moments where students talked about mathematics. Connecting back to technology, document cameras allow students to showcase their work while discussing their thoughts and solutions. They also provide opportunities for teachers to examine students' mathematical notation and writing. Out of the eight attitude profiles, the four profiles containing a negative emotional dimension had the least number of references coded to specific content descriptions.

Attitude Profile Descriptions

The attitude profile descriptions, presented in the results section, are sufficiently detailed to delineate differences between real-time classroom activities that impact students' attitudes toward mathematics. Researchers and practitioners can think about each attitude profile as a node interconnected. The connections represent the classroom factors contributing to traveling between nodes or attitude profiles, with the goal of navigating from less desirable to more desirable profiles by implementing the strategies discussed in this section.

Recommendations for Teachers

Table 17 presents several important quotes from students in the study relative to research connections. A list of teacher recommendations is provided for teachers to examine in relation to their own classrooms and practices.

Table 17

Important Student Quotes Connected to Research

Quote	Research Connections	Teacher Recommendations
M120317: I realized that like in the beginning before we did [this study] I thought math would be hard but after I saw like the five minutes on it and how what was going on in five minutes I realized…that it should be fairly easy.	Peak learning times tend to occur at the beginning and end of sessions and breaking sessions into smaller blocks of time, with breaks between blocks, can free up working memory and improve the processing of information (Sousa, 2017).	Present new material first. Use down time for activities. Divide learning objectives into sublearning objectives. Allow for closure at the end of objectives
E20619: I realized that like we sit around more now and usually I thought like we kinda did more stuff at the beginning, but when like [the journal protocol] asks like what are you doing in the past five minutes, it's kinda like we're just sitting and doing problems the entire time and not really like getting up and doing anything.	Exercise and movement reduce cortisol, increases the number of capillaries in the brain, and increases oxygen concentration levels in the blood thereby resulting in enhanced cognitive performance and increases in episodic memory (Sousa, 2017).	Invite students to act out mathematical concepts such as locations of points on a number line. Allow students to collaborate and move among groups during down times. Use document cameras to allow students to share and discuss solutions.

Quote	Research Connections	Teacher Recommendations
M10316: In math we don't really get to choose anything. [The teacher] just tells us what to do and doesn't give us a choice.	Student choice introduces novelty into learning making it more interesting (Sousa, 2016). Student choice aligns to Universal by Design (UDL) principles (CAST, 2011). Students produce higher quality work and express greater satisfaction and less apprehension in their work when given choices on assignments compared to students with less autonomy (Sousa, 2016).	Provide choice in assignments and learning activities aligned to the same learning objectives. Reduce the volume of tests and quizzes by using student choice projects aligned to students' talents and interests.
T105K7: I have no clue how to do this even though we've been doing it for a while. It's probably because it gets really boring so I space off. I'm most likely gonna fail everything about this.	The use of novelty can make teaching and learning more interesting (Sousa, 2016).	Integrate the appropriate use of technology, games, music, and movement and encourage student choice on assignments. Allow students to choose activities connected to learning outcomes.
D01015: I found that it was kinda interesting to occasionally take a break and then look back at what we had been doing over the past over the past few minutes. And so, I also it also kinda made me reevaluate how I understood mathematics and like how I thought about it…and so I thought…so, I never thought of that before. And so that caused me to think a little bit. So… I came out of this knowing more than I did before.	Critical reflection and writing about mathematics have positive impacts on students' affective responses toward mathematics while giving students a sense of control over their learning and promoting feelings of accomplishment (Powell & López, 1989).	Allow breaks where students can self-reflect on what they have learned. Allow opportunities for students to write about what they have learned.

Quote	Research Connections	Teacher Recommendations
K01118: For once I actually feel good about math because I actually understand it right now.	Students move along in school unmotivated as education is not a core job they are trying to accomplish; a core job students try to engage in everyday, while at school, is feeling successful (Christensen et al., 2011).	Scaffold problems to allow students multiple entry points. Use formative assessments. Provide student choice that allows students to connect material to their passions, interests, and talents. Provide timely and detailed feedback.
	A constant theme impacting students' attitudes toward mathematics is low perceived competence which is reinforced by repeated failures (Di Martino and Zan, 2009).	Aid students in focusing on feedback as learning opportunities. Deemphasize exams and quizzes.
	Students need to feel physically and emotionally safe before cognitive processing can occur and strong negative reactions toward mathematics can result in anxiety and the avoidance of new learning situations (Sousa, 2017). The overreliance on speed and timed test creates fear and shuts down students' working memories (Ruef, 2018).	Do not overemphasize speed as a means of judging those that are good at mathematics. Recognize that all students learn differently and at different paces.

Note. Codes before quotes are students' unique identifiers.

Table 18 presents specific teacher intervention strategies for working with students in each attitude profile based upon the key characteristics presented in each profile.

Table 18

Attitude Profiles and Teacher Intervention Strategies

Attitude Profile	Teacher Intervention Strategies
Positive-Relational-High (PRH)	Students in the PRH profile have positive impressions of their teachers and their teachers' abilities to support their learning. Seek to keep students within this profile by using technology, games, and real-world connections. Students in this profile describe an intrinsic relational understanding of mathematics, rarely cite talking about mathematics or engaging in student-directed activities, and often do not feel challenged. Challenge PRH students to understand mathematics as a set of relationships through student-directed explorations and allow them to discuss their understandings of mathematics. Seek to increase the complexity of tasks (e.g., by focusing on conceptual underpinnings such as which linear relationships are directly proportional relationships and "why") for these students while maintaining the difficulty level (e.g., do not increase the number of steps and procedures—vary the complexity by focusing on "why" and "how" concepts work).
Positive-Relational-Low (PRL)	These students tend to have positive self-perceptions as mathematics learners but are tentative about their perceived confidence due to successes experienced. A noticeable difference between these students and students in the PRH profile is that PRL students never cite positive impressions of their teachers or indicate that they receive help from their teachers. Consider all recommendations for PRH students. Additionally, carefully scaffold activities so students experience success. Check in with them frequently and help them understand productive struggle as an important step in mathematical learning. Make certain they analyze mistakes and use them as learning opportunities.
Positive-Instrumental-High (PIH)	Focus on the same strategies noted for PRH students and note that like PRH students, PIH students express the desire to be challenged. However, unlike PRH students, PIH students start to cite mathematics as boring and are slightly less likely to mention their perceptions of their teachers or cite help from their teachers. Moving students to a relational understanding of mathematics is likely an issue of exposure. Deliberately focus on making connections across ideas and understanding problems from multiple perspectives (e.g., ask students to show how to divide two fractions using the traditional algorithm, explain why it works and how it connects to the structure of our number system, and model the division using a number line).
Positive-Instrumental-Low (PIL)	Students in the PIL profile often recognize that they are getting content correct but cite that they do not understand what they are doing or refer to the material as confusing. These students tend to have mixed reactions to many classroom activities specifically tied to the successes they experience. Combine the intervention strategies for PRL and PIH students. Check in with these students frequently, scaffold activities for success, and aid them in understanding productive struggle. Allow these students plenty of time to explain their thinking and how they are feeling about mathematics.

Attitude Profile	Teacher Intervention Strategy
Negative-Relational-High (NRH)	NRH is an extremely rare profile. Compared to their PRH peers, NRH students rarely mention mathematics as enjoyable, which was the dominant perception of PRH students. They also rarely mention their perceptions of their teachers. Check in with these students often and provide students choices on assignments, aligned to the learning outcomes, that allow them to connect mathematics to their passions and interests. NRH students rarely mentioned group work but had positive perceptions working together. Implementing group projects where students propose their own research questions connected to their interest might be sufficient to move these students to the PRH profile.
Negative-Relational-Low (NRL)	NRL students tend to experience failure more often than success, overwhelmingly describe mathematics as boring, and rarely provide detailed content descriptions. They have negative perceptions of their teachers and tests and quizzes. Implement the strategies in the NRH profile by appropriately scaffolding assignments for success and consider using technology and games more frequently for these students.
Negative-Instrumental-High (NIH)	NIH students have positive self-perceptions as learners of mathematics and often find the material too easy. These students are the least likely, out of all profiles, to provide detailed content descriptions. Focus on time for students to write about mathematics and how they think and feel about what they are learning. Challenge them to make connections within and across ideas using strategies from the PIH profile while allowing them choices in assignments to discover connections to their talents and interests. These students need to find mathematics interesting and need to be challenged.
Negative-Instrumental-Low (NIL)	NIL students likely carry anxiety, failures, and traumatic events with them from previous experiences. Show these students that you care about them and value them by spending significant time getting to know them. Focus on establishing what they can do rather than what they cannot do. Create numerous opportunities for them to experience success through scaffolding and student-choice assignments. Take a slow and measured approach to course competencies while still maintaining the same high standards as for all students. These students need to feel that school is a safe and nurturing environment and that they are valued before they can learn. Value their voice and allow them opportunities to shape their learning environments. Consider involving these students in mini-action research projects that help shape a positive classroom culture and climate.

Limitations

It is difficult to generalize results from phenomenological and qualitative research and the interpretations are subject to the researcher's biases. In this study, I mitigated biases through bracketing exercises, and the in-depth descriptions of the attitude profiles aid in transferability. Purposeful and maximum variation sampling are not random sampling methods, and the samples in this study should not be considered representative of all schools in each performance level.

The chi-square tests provided valuable insight into the data and connections to previous research, but the sampling method does not meet the necessary conditions for running the tests. However, as the study was inductive in nature, the results provide important information for research and practice. The volume of data collected along with the number of random moments captured in the classroom through the ESM aid in confidence in the results.

The study was logistically very complex and will provide some challenges for replication. Limiting the distance between the researcher and participants likely would have resulted in more detailed student responses and interviews. However, maintaining distance was necessary to not influence what was happening in the classroom. As no coresearchers participated in the study, interrater reliability was not possible. However, I completed all coding in a relatively short period of time following a detailed list of rules and entered data into a database; I transcribed all interviews verbatim, and I studied the data over an extended period of time through multiple methods.

The descriptions of the attitude profiles were limited by the classroom activities observed. However, all classrooms in the study were remarkably similar in terms of classroom activities. So, it is possible that the study captured the activities most typical of middle-school classrooms. The repeated nature of the study and volume of statements analyzed could have resulted in dominant voices over representing moments in the classroom. However, the possibility of dominant voices was mitigated by looking both within and across journals over time and not relying solely on frequency analysis.

Recommendations for Future Research

A natural extension of any inductive qualitative research is to operationalize the variables discovered and attempt to generalize. Numerous directions are possible, including examining associations between school-wide performance and attitude profiles, creating new attitude scales based on the real-time classroom factors identified in this study, and using generalized linear mixed models to determine the extent to which the variables identified through the qualitative work contribute to the various attitude profiles.

Additional qualitative work is possible, including developing the connections between attitude profiles. For example, a potential difference between the PRH and PIH profile was feeling challenged. Challenging students by focusing on building connections between mathematical ideas could move students from the PIH profile to the PRH profile. Unlike students in the PRH profile, students in the PRL profile never cited receiving help from their teachers and rarely expressed positive perceptions of their teachers. Additional teacher support with a sustained focus on developing independent learners could move students from the PRL profile to the PRH profile. A model illustrating these key connections can result in important intervention strategies and begin to shift students' attitudes and performance in mathematics and interest in STEM fields.

Historically, researchers used beepers to accomplish the ESM. This study provided a viable method to revitalize an important sampling technique using current technology. The methods outlined extend beyond the mathematics classroom and can easily be modified for other content areas and school culture and climate studies.

The methodology and research methods outlined can easily be adapted to an action research model in which students act as collaborators in the learning community. Students can set up the signaling protocols and procedures, organize the packets, collect, and analyze the data, and provide recommendations to their teachers, administrators, and larger community. In doing so, students will engage in making real-world connections and using technology while increasing self-worth and having a voice for change. These are all origins of the most desirable attitude profile, positive-relational-high (PRH).

Final Thoughts

The study helped participants move toward a better understanding of themselves, their attitudes, and the world, while focusing on critical growth and empowerment. The results of the study provide hope for the field of mathematics education as students, who are experiencing their first middle-school mathematics course, generally have positive self-perceptions as learners of mathematics. Moreover, students demonstrated their attitudes toward mathematics develop and change in fluid and flexible ways through a variety of classroom experiences.

Students crave safe, nurturing, fun, and challenging classroom environments that respect and value every student. They want to explore connections to their environments through games and technology. Experiencing repeated failure, due to the overemphasis of test and quizzes, degrades students' attitudes toward mathematics and is counterproductive to increasing students' interests in STEM fields. Implementing student choice empowers students to shape their learning environments while developing into strong independent learners. Students are helping educators understand how to shape the future of education. It is time to listen.

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References

ACT. (2017). *STEM education in the U.S.: Where we are and what we can do | 2017*. https://www.act.org/content/dam/act/unsecured/documents/STEM/2017/STEM-Education-in-the-US-2017.pdf

Aiken, L. R. (1976). Update on attitudes and other affective variables in learning mathematics. *Review of Educational Research*, *46*(2), 293–311. https://doi.org/10.3102/00346543046002293

Aiken, L. R., & Dreger, R. M. (1961). The effect of attitudes on performance in mathematics. *Journal of Educational Psychology*, *52*(1), 19–24. https://doi.org/10.1037/h0041309

Allport, G. W. (1935). Attitudes. In C. A. Murchinson (Ed.), *A handbook of social psychology* (pp. 798–844). Clark University Press.

Andrusiak, R. A. (2018). *Real-time classroom factors impacting middle-school students' attitudes toward mathematics* (Publication No. 10933664) [Doctoral dissertation. New England College]. ProQuest Dissertations and Theses Open.

Andrusiak, R. A., Bastoni, A., Fitzgerald, C. J., Geraghty, C., Laurian-Fitzgerald, S., & Petruno-Goguen, R. (2020). *From the inside-out: Concrete steps to transforming education today*. Rowman & Littlefield.

Business Higher Education Forum. (November 2011). *Meeting the STEM workforce challenge: Leveraging higher education's untapped potential to prepare tomorrow's STEM workforce* [Policy brief]. http://eric.ed.gov/?id=ED527257

Business Higher Education Forum. (2017, April 05). *Business engagement models to increase undergraduate STEM student persistence*. http://www.bhef.com /sites/default/files/BHEF_17_NSF_03-29-17%20Final.pdf

CAST. (2011). *Universal design for learning guidelines*. http://www.udlcenter.org/aboutudl/udlguidelines_theorypractice

Choi, N., & Chang, M. (2011, January 01). Interplay among school climate, gender, attitude toward mathematics, and mathematics performance of middle school students. *Middle Grades Research Journal, 6*(1), 15–28.

Christensen, C., Johnson, C. W., & Horn, M. B. (2011). *Disrupting class: How disruptive innovation will change the way the world learns*. McGraw-Hill.

Colaizzi, P. F. (1978). Psychological research as the phenomenologist views it. In R. Vaile & M. King (Eds.), *Existential phenomenological alternatives for psychology* (pp. 48–71). Oxford University Press.

Creswell, J. W. (2013). *Qualitative inquiry and research design: Choosing among five approaches* (3rd ed.). SAGE Publications.

Creswell, J. W. (2014). *Research design: Qualitative, quantitative, and mixed methods approaches* (4th ed.). SAGE Publications.

DeBellis, V., & Goldin, G. A. (1999). Aspects of affect: Mathematical intimacy, mathematical integrity. In O. Zaslavsky (Ed.), *Proceedings of the 23rd Conference of the International Group for the Psychology of Mathematics Education: Vol. 2.* (pp. 249–256).

Dewey, J. (1922). *Human nature and conduct: An introduction to social psychology*. Henry Holt and Company.

Di Martino, P., & Zan, R. (2003, July). *What does "positive" attitude really mean?* Paper presented to the International Group for the Psychology of Mathematics Education, Honolulu, HI.

Di Martino, P., & Zan, R. (2009). 'Me and maths': Towards a definition of attitude grounded on students' narratives. *Journal of Mathematics Teacher Education*, *13*(1), 27–48. https://doi.org/10.1007/s10857-009-9134-z

Dubina, K., Morisi, T., Rieley, M., & Wagoner, A. (2019). Projections overview and highlights, 2018–28. *Monthly Labor Review*. https://doi.org/10.21916/mlr.2019.21

Hannula, M. S. (2002). Attitude toward mathematics: Emotions, expectations and values. *Educational Studies in Mathematics*, *49*(1), 25–46. https://doi.org/10.1023/A:1016048823497

Hannula, M. S., Martino, P. D., Pantziara, M., Zhang, Q., Morselli, F., Heyd-Metzuyanim, E., Lutovac, S., Kaasila, R., Middleton, J. A., Jansen, A., & Goldin, G. A. (2016). *Attitudes, beliefs, motivation and identity in mathematics education: An overview of the field and future directions*. Springer. https://doi.org/10.1007/978-3-319-32811-9

Hattie, J. (2009). *Visible learning: A synthesis of over 800 meta-analyses relating to achievement*. Routledge.

Idil, F. H., Narli, S., & Aksoy, E. (2016). Using data mining techniques examination of the middle school students' attitude towards mathematics in the context of some variables. *International Journal of Education in Mathematics, Science and Technology*, *4*(3), 210–228. https://doi.org/10.18404/ijemst.02496

Kolb, L. (2015, March 5). Is technology a gimmick in your classroom? *ISTE*. https://www.iste.org/explore/In-the-classroom/Is-technology-a-gimmick-in-your-classroom%3F

Larson, R., & Csikszentmihalyi, M. (1983). The experience sampling method. In H. G. Reis (Ed.), *Naturalistic approaches to studying social instruction* (pp. 42–56). Jossey-Bass Publishers.

Ma, X., & Kishor, N. (1997). Assessing the relationship between attitude toward mathematics and achievement in mathematics: A meta-analysis. *Journal for Research in Mathematics Education*, *28*(1), 26–47. https://doi.org/10.2307/749662

Mandler, G. (1984). *Mind and body: Psychology of emotion and stress*. W.W. Norton.

Mata, M. D., Monteiro, V., & Peixoto, F. (2012). Attitudes towards mathematics: Effects of individual, motivational, and social support factors. *Child Development Research*, *2012*, 1–10. https://doi.org/10.1155/2012/876028

McLeod, D. (1992). Research on affect in mathematics education: A reconceptualization. In D. A. Grouws (Ed.), *Handbook of research on mathematics teaching and learning* (pp. 575–596). Macmillan.

Mitra, D. L. (2009). Student voice and student roles in educational policy and policy reform. In G. Sykes, B. L. Schneider, D. N. Plank, & T. G. Ford (Eds.), *Handbook of education policy research* (pp. 819–830). Routledge.

Moustakas, C. (1994). *Phenomenological research methods*. SAGE Publications.

Mullis, I. V. S., Martin, M. O., Foy, P., & Hooper, M. (2016). *TIMSS 2015 international results in mathematics.* http://timssandpirls.bc.edu/timss2015/international-results/

National Science Board, & National Science Foundation. (2020). *Science and engineering indicators 2020: The state of U.S. science and engineering* (NSB-2020-1). https://ncses.nsf.gov/pubs/nsb20201/

Neale, D. C. (1969). The role of attitudes in learning mathematics. *The Arithmetic Teacher*, *16*(8), 631–640.

OECD. (2013). *PISA 2012 results: Ready to learn?: Students' engagement, drive and self-beliefs (Volume III)*. PISA, OECD Publishing. https://doi.org/10.1787/9789264201170-en

Powell, A. B., & López, J. A. (1989). Writing as a vehicle to learn mathematics: A case study. In P. Connolly & T. Vilardi (Eds.), *The role of writing in learning mathematics and science* (pp. 157–177). Teachers College Press.

Preble, B. & Gordon, R. (2011). *Transforming school climate and learning*: *Beyond bullying and compliance.* Corwin.

Ravitch, D. (2014). *Reign of error: The hoax of the privatization movement and the danger to America's public schools*. Vintage Books.

Ravitch, D. (2016). *The death and life of the great American school system: How testing and choice are undermining education*. Basic Books.

Ravitch, D. (2020). *Slaying Goliath: The passionate resistance to privatization and the fight to save America's public schools*. Alfred A. Knopf.

Ruef, J. (2018, November 6). How to help students heal from 'math trauma'. *Education Week Teacher*. https://www.edweek.org/tm/articles/2018/11/06/how-to-help-students-heal-from-math.html

Ruffell, M., Mason, J., & Allen, B. (1998). Studying attitude to mathematics. *Educational Studies in Mathematics*, *35*(1), 1–18. https://doi.org/10.1023/a:1003019020131

Sarason, S. B. (1990). *The predictable failure of educational reform: Can we change course before it's too late?* Jossey-Bass Publishers.

Schofield, H. L. (1982). Sex, grade level, and the relationship between mathematics attitude and achievement in children. *The Journal of Educational Research*, *75*(5), 280–284. https://doi.org/10.1080/00220671.1982.10885395

Schwab, K. (Ed.). (2016). *The global competitiveness report 2016-2017*. World Economic Forum. http://www3.weforum.org/docs/GCR2016-2017/05FullReport/TheGlobalCompetitivenessReport2016-2017_FINAL.pdf

Schwab, K. (Ed.). (2019). *The global competitiveness report 2019*. World Economic Forum. http://www3.weforum.org/docs/WEF_TheGlobalCompetitivenessReport2019.pdf

Sousa, D. A. (2016). *Engaging the rewired brain*. Learning Sciences International.

Sousa, D. A. (2017). *How the brain learns* (5th ed.). Corwin.

Thomas, W. I., & Znaniecki, F. (1918). *The Polish peasant in Europe and America: Monograph of an immigrant group* (Vol. 1.). Richard G. Badger.

Tulving, E., & Thomson, D. M. (1973). Encoding specificity and retrieval processes in episodic memory. *Psychological Review*, *80*(5), 352–373. https://doi.org/10.1037/h0020071

Wilkins, J. L., & Ma, X. (2003). Modeling change in student attitude toward and beliefs about mathematics. *The Journal of Educational Research*, *97*(1), 52–63. https://doi.org/10.1080/00220670309596628

Zan, R., & Di Martino, P. (2007). Attitude toward mathematics: Overcoming the positive/negative dichotomy [Monograph]. *The Montana Mathematics Enthusiast, 3,* 157–168.

Appendix A

Student ESM Protocol

Please fill out a Unique Student Identifier using the instructions to the right.

Box 1	Box 2	Box 3	Box 4

Unique Student Identifier Instructions

Box 1 – Enter your middle initial or initials.

Box 2 – Enter the number of older siblings you have.

Box 3 – Enter your two-digit birth month.

Box 4 – Enter a 1 if you have pets or a 0 if you do not have pets.

1) Describe what is currently happening or happened during the past five minutes?

2) Please check the emoticon that **best** represents how you are currently feeling about mathematics?

Please explain anything that happened during the observation period that contributed to your choice.

Please fill out a Unique Student Identifier using the instructions to the right.

Box 1	Box 2	Box 3	Box 4

Unique Student Identifier Instructions

Box 1 – Enter your middle initial or initials.

Box 2 – Enter the number of older siblings you have.

Box 3 – Enter your two-digit birth month.

Box 4 – Enter a 1 if you have pets or a 0 if you do not have pets.

1) Describe what is currently happening or happened during the past five minutes?

2) Please place a check mark in the blank closest to the word that **best** describes how you are currently feeling about mathematics.

NOT SMART _____ _____ _____ _____ _____ SMART

3) Please explain what happened, or what you or the teacher were doing, when you received the text message for the study, that helped you feel good about learning math or that made you feel not so good about learning math.

Please fill out a Unique Student Identifier using the instructions to the right.

Box 1	Box 2	Box 3	Box 4

Unique Student Identifier Instructions

Box 1 – Enter your middle initial or initials.

Box 2 – Enter the number of older siblings you have.

Box 3 – Enter your two-digit birth month.

Box 4 – Enter a 1 if you have pets or a 0 if you do not have pets.

1) Describe what is currently happening or happened during the past five minutes?

2) Please circle the option that **best** describes how you understand mathematics.

   a) Mathematics is a set of rules to be applied to solve problems.

   b) Mathematics is a method for understanding connections across ideas and why procedures work.

   Please explain what happened, or what you or the teacher were doing, when you received the text message for the study, that made you see or understand math this way.

3) In your own words, describe how you feel right now about yourself as a mathematics learner.

Appendix B

Student Interview Protocol

I am a graduate student at New England College conducting the study that recently occurred in your mathematics classroom. I would like to ask you a few questions about your experience with the study. I have five questions and the interview should take about ten minutes.

I would like to ask that you begin by choosing a pseudonym. A pseudonym is a fictitious name. This will help keep your responses confidential and I will use this pseudonym from this point on when I refer to you. Can you please tell me what pseudonym you would like to choose?

I will now turn on the recorder.

Please confirm that you have previously agreed to participate in this interview process, and you have signed the form indicating this agreement. This form was sent home at the beginning of the study.

Thank you for agreeing to speak to me about your experience in this study.

1. Please tell me a little about your experience participating in the study over the past three months. What was it like for you?
2. What did you like about being a part of this study?
3. What did you dislike about being a part of this study?
4. Do you think your attitude toward math tends to stay the same or change over time?
5. Tell me a little more about how you think and feel about doing math.
6. What happens in the classroom on a day-to-day basis that impacts how you think and feel about doing math?
7. Did participating in the study have any impact on how aware you are of classroom factors that contribute to how you think and feel about doing math?
8. Is there anything else you would like to tell me about participating in this study or your attitude toward mathematics?