The Influence of Teaching Instruction and Learning Styles on Mathematics Anxiety in the Developmental Mathematics Classroom

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ABSTRACT

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In the US, an estimated 25% of four-year college students and up to 80% of community college students suffer from a moderate to high degree of mathematics anxiety (MA) (Chang & Beilock, 2016). Many scholars have noted that mathematics anxiety can be regarded as a significant factor in determining a student's achievement and mathematics related jobs.

In the existing literature body, many researchers noted that MA may stem from teaching methods that are more conventional and rule-bounded such as lecture-style classroom models. On the other hand, MA can be mitigated by inquiry-based learning classroom models where students construct knowledge through inquiry, communication, critical thinking, and group work. However, the current literature has not built the connection between different teaching styles and students' individual differences with respect to MA. The individual differences are associated with the personality of the learner, learning styles, learning speed, and needs and interests of the learner. Depending on a student's learning style and a compatible teaching style, the student may actively participate in their own learning with less mathematics anxiety. Thus, the purpose of this study is to determine the influence of different teaching styles on MA, when interacted with Kolb's and Gregorc's (1984) four different learning and thinking styles. The research questions investigated in this study are: 1) What is the difference between a lecture classroom model (LCM) and an inquiry-based learning classroom model (IBL) on students' mathematics anxiety levels over a fifteen-week semester of a college-level remedial

mathematics course?; 2) What is the difference between a lecture classroom model (LCM) and an inquiry-based learning classroom model (IBL) on mathematics anxiety levels for students with different learning and thinking styles (as defined by Kolb's and Gregorc's learning styles) over a fifteen-week semester?; and 3) What aspects of instructional approaches (LCM and IBL) do students with different learning and thinking styles report as being related to mathematics anxiety? The abbreviated version of the mathematics anxiety rating scale (A-MARS), Kolb's learning styles inventory, Gregorc's thinking styles, and Written questionnaire were used to measure students' MA levels and identify their learning and thinking styles.

The results provided evidence that IBL instruction is beneficial for the students with MA, especially with mathematics test anxiety and mathematics course anxiety. Only numerical task anxiety was not significant. Thus, student-centered learning pedagogies turned out to be an effective and engaging method for lowering MA. However, there was no evidence to support the overall relationship between the constructs of learning and thinking styles and MA levels, above and beyond the instructional approaches. Classifying students according to learning and thinking styles did not influence students' MA levels in this study over the 15 academic weeks. Moreover, after a 15 academic weeks, students in both LCM and IBL classes responded positively to key components of LCM and IBL classroom models. This implies that both LCM and IBL approaches still are important models regardless of students' MA level.

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Again, it was only possible through their support, love, and prayers that I am today. My deepest gratitude and love go out to them. Thank you.

DEDICATION

To my family,

Do not be anxious about anything, but in every situation, by prayer and petition, with thanksgiving, present your requests to God. And the peace of God, which transcends all understanding, will guard your hearts and your minds in Christ Jesus.

Philippians 4:6-7

CHAPTER I

INTRODUCTION

Need for Study

Many students at middle school, high school, and college level experience mathematics anxiety (MA). MA involves feelings of tension and anxiety that interfere with the manipulation of numbers and the solving of mathematical problems in a wide variety of ordinary life and academic situations (Richardson & Suinn, 1972). In the U.S., an estimated 25% of four-year college students and up to 80% of community college students suffer from a moderate to high degree of MA (Chang & Beilock, 2016). Many researchers have noted that MA can be regarded as a significant factor in determining students' achievement. Various studies, for example, have found significant negative correlations between MA and academic performance (e.g., Ashcraft & Kirk, 2001; Luigi et al., 2007).

For the students in community college mathematics courses, academic performance is influenced by a variety of factors including, but not limited to, MA. Research has indicated that teachers and teaching style can play an important role for both students' academic performance and also, in their levels of MA. Most existing research has considered how teacher's instruction influences the MA of their students. Darling-Hammond (2004), for example, found that teachers are one of the most influential factors affecting student achievement. Furner and Berman (2003) discussed how "one-size-fits-all" instruction, rote learning, and the use of assignments as punishment could contribute to increased levels of MA. Instructional approaches in community college mathematics courses, it seems, may be part of the problem with regard to students' MA. There are two aspects of this from the literature that the researcher elaborates on.

First, current literature has suggested that *particular* instructional approaches may be part of the problem with respect to MA. That is, these studies have investigated the relationship between a teacher's instruction and the MA of students in that course. Teachers play an essential role in the different components of education, such as curriculum design, instruction, and assessment. Luigi (2007) and Kirk (2001) argued that MA may stem from teaching methods that are more conventional and rule-bound. That is, classrooms where a teacher may emphasize getting the right answer, where students may be asked to mimic rules and procedures presented to them and complete rote practice problems, and where students have fewer opportunities to be inherently connected with others in cooperative learning. Such instructional approaches typically adhere to a lecture classroom model (LCM). The practices of LCM likely produce anxiety because students are asked to learn prescribed rules or procedures without necessarily having made sense of them for themselves. Being called upon to answer a question without necessarily understanding why a particular answer or procedure makes sense can be anxiety inducing: it puts the learner in a subordinate position where they cannot defend whether their approach is right or wrong because it was not theirs in the first place. Indeed, Borasi and Rose (1989) found that students under such instructional approaches are often content with externally manipulating symbols and doing routine problems, without reaching a deep and personal understanding of the material.

In contrast, in a more reform-oriented and an inquiry-based learning classroom model (IBL), students are encouraged to conjecture, discover, solve, explore, collaborate, and communicate without a teacher laying out all of the formulas, theorems, and examples as previous knowledge (Capaldi, 2015). Diggs (2009) stated that inquiry is a process of learning driven by questioning, thoughtful investigation, making sense of information, and developing new understandings. Useful questions in an IBL can be "What do you already know that might be useful here?”, Can you form any hypothesis?”, “Can you think of any counterexamples?" or "How can you best display your data?" These questions intended to help students be flexible in their thinking, and to provide agency for students in the learning process. By avoiding some of the problematic issues of LCM approaches, seen to be the primary cause of why students in LCM models often have MA, IBL approaches in mathematics instruction are seen as productive with respect to decreasing MA. Indeed, many researchers have shown that IBL reduces students’ MA by focusing on students’ conceptual understanding of mathematics content (Lubinski & Otto, 2004; Sloan, 2010). Inquiry and individual development in IBL can promote a positive attitude towards mathematics (Woodard, 2004), which implies that students can overcome MA in IBL.

Second, literature has suggested that not appropriately differentiating instruction to take into account students’ different learning styles may be part of the problem with respect to MA. That is, these studies have to some degree, investigated the relationship between a student’s learning style and the MA of that student. Scholars stated that it is important for teachers to prepare to facilitate, structure, and validate successful learning in the classroom for all students’ individual differences (Guild, 1994). This is because each learner has different preferences as she or he processes information during classroom instructions. Some studies have found a correlation between teaching strategies and learning styles to enhance students’ academic achievement (Akdemir and Koszalka, 2008). This implies that identifying the most appropriate form of instruction with respect to learning style can reduce MA, which has a negative correlation with academic achievement. Among various learning styles that have been conceptualized, Kolb’s and Gregorc’s models are chosen for this study; in the methodology section, this decision is justified further. I reserve the term *learning styles* to refer to Kolb's model, and *thinking styles* to refer to Gregorc's model; I do so to help differentiate the two for the reader, and because, although similar, there are slight differences between the two models that this distinction helps capture. In Kolb's experiential learning style theory (1984), learners tend toward one of four types of *learning styles*: 1) diverging, 2) assimilating, 3) conversing, and 4) accommodating. These primarily differentiate preferences for learning – ways that help one acquire new knowledge. His learning styles, in particular, potentially align with the two instructional models described previously (e.g., Felder & Brent, 2005; Tulbure, 2012). The Gregorc's thinking styles theory (1984) is similar in manner to Kolb's learning style where the assessment contains four different quadrants of learning preference modes within in the *thinking style* model: 1) concrete sequential, 2) abstract random, 3) abstract sequential, and 4) concrete random. According to Oxford (1995), the opportunity for every child to succeed depends upon the teacher having a full understanding of learning styles. This is because teachers can use different methods of gathering, processing, interpreting, organizing and analyzing information for students' learning and their learning environment. Many researchers have confirmed that effective teaching provides instruction that responds to learners' individual needs (Arthurs, 2007; Beck, 2001; Tomlinson, 2001). This is because the students who have different learning and thinking styles are influenced by different teaching strategies. Such research indicates that understanding students' different learning and thinking styles has been significant in reducing students' anxiety in learning mathematics. As a result, the National Council of Teachers of Mathematics (NCTM) has suggested that teachers need to use a variety of instructional techniques and strategies to benefit all types of learners in the classroom (NCTM, 2000).

However, while the research has indicated that both IBL instructional approaches and differentiating instruction based on learning and thinking styles can each play a role in mitigating MA, this study investigates the degree to which these are interdependent (and not independent). The researcher investigates the idea that not only teachers' instruction in mathematics but how it also interacts with students' different learning and thinking styles that influence students' MA (Figure 1). The idea is that for some students, a rote-teaching style may tend to induce anxiety (as identified from the literature), but that for others, a more open-ended inquiry teaching style may tend to cause anxiety in one's mathematical learning. This is sensible as well. For some students, more anxiety might be produced in situations where they are required to be active in their learning, asked to struggle to understand an idea, or required to communicate and interact with peers. Group work in IBL approaches might cause communication apprehension for students who lack social skills, or might cause heightened anxiety for students who always want to know and to have the right answer. This study explores this issue.

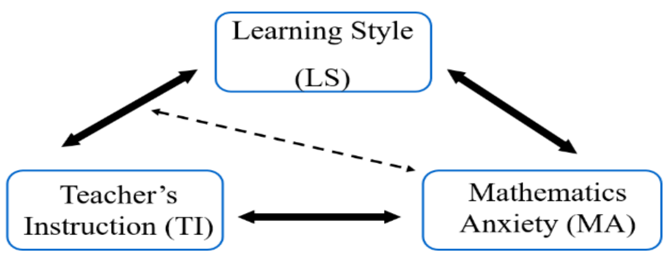


Figure 1. The influence of both learning styles and teaching instruction on mathematics anxiety

Note. The three solid arrows imply each relationship among learning style, teaching instruction, and mathematics anxiety. The dotted arrow shows that there is the influence of both learning style and teaching instruction on mathematics anxiety.

Purpose of Study

The purpose of this mixed methods study is to investigate the influence of two different instructional models on MA, interacting with Kolb's (1984) and Gregorc's (1984) four different learning and thinking styles. Depending on students' learning and thinking styles, teachers may expect that students actively participate in their own learning with less MA. Some students could naturally develop an effective and appropriate range of their learning behaviors depending on their own learning and thinking styles, but other students might not recognize their learning and thinking styles to be cognitively, affectively, and meta-cognitively engaged through task selection, classroom discourse, and modeling of effective strategic learning behaviors. Every student has a different learning and thinking style, and this paper intends to observe how teachers' instructional approaches and students' different learning and thinking styles are associated with students' MA and academic performance. Specifically, the research questions to be answered are:

1. What is the difference between a lecture classroom model (LCM) and an inquiry-based learning classroom model (IBL) on students' mathematics anxiety levels over a fifteen-week semester of a college-level remedial mathematics course?
2. What is the difference between a lecture classroom model (LCM) and an inquiry-based learning classroom model (IBL) on mathematics anxiety levels for students with different learning and thinking styles (as defined by Kolb's and Gregorc's learning styles) over a fifteen-week semester?
3. What aspects of instructional approaches (LCM and IBL) do students with different learning and thinking styles report as being related to mathematics anxiety?

Procedure

Participants

This study investigated 185 students, 88 of whom learned in a lecture classroom model (LCM), and other 97 of whom learned in an inquiry-based learning classroom model (IBL) at a community college by coordinating 10 different instructors (Appendix B for recruitment email). Each group of students was divided into five classrooms of at most twenty-five students each. The instructors in the two different models were distinguished by a training session: the instructors who taught IBL had 7 days of professional development offered by the mathematics department at the community college. They were trained to understand the importance of student-centered learning pedagogies and to apply IBL strategies into their remedial mathematics courses in the following semester.

On the other hand, the other instructors who taught the LCM classes had no training session, and they were expected to teach based on a traditional way of teaching mathematics courses. Therefore, five instructors taught LCM, and the other five taught IBL, so there were ten classes total: LCM_1, LCM_2, $LCM_{3,}$ $LCM_{4,}$ $LCM_{5,}$ IBL_1, IBL_2, IBL_3, IBL_4, and IBL_5 (Table 1). Prior to the study beginning, the researcher ensured that the instruction of these ten instructors was relatively uniform across all classes within each model. That is, the instructors of each of the five LCM classes were, in fact, using a similar LCM approach in their teaching, and the same for the instruction of the five IBL class instructors.

Table 1. Study participants in two different instructional models

MAT 56		
Instructional Model	LCM	IBL
# of Instructors	5	5
# of IBL training that each instructor had	0	7 days
Total number of Participants (n = 185)	88	97

Note. The Instructions who did not have an inquiry-based learning training were expected to teach in a lecture style. The instructors who had 7 days of professional development were expected to use the strategies of inquiry-based learning in their class.

Instrument

The researcher coordinated with each of the ten instructors to collect data using three different survey instruments: The Learning Style Inventory (LSI) by Kolb (1984), the Thinking Styles by Gregorc's (1984), and the Abbreviated Version of the Mathematics Anxiety Rating Scale (A-MARS) by Alexander (1989). These surveys were used to measure students' different learning styles and their MA levels.

Learning Style Inventory (LSI) (Kolb, 1984). The relationship between mathematics anxiety (MA) and learning styles has been studied, but there were not many studies that show the relationship between the MA and the compatibility between learning styles and teaching styles. Among many learning styles that has been studied, the Kolb's model was chosen for this study due to the depth of the research over many years, emotional and psychological aspects of the experiential learning theory, and its compatibility with the Lecture Classroom Model (LCM) and Inquiry-Based Lecture Classroom Model (IBL) that was utilized in this study. For example, one of the learning styles in Kolb's model, "assimilating," is estimated to be compatible with LCM because they prefer to learn through clear explanation. Another study showed that "divergers" respond best to group projects and all types of discussion (Tulbure, 2012), which is compatible with IBL. Therefore, Kolb's model was chosen for this present study over the other learning styles because it was considered that the learning styles from the Kolb's model were most easily matched with either LCM or IBL style addressed in this study.

The goal of the Learning Style Inventory (LSI) was to measure how closely a student matches with each learning style. The LSI consisted of ten items to describe participants' four-stage cycle: Concrete Experience (CE), Reflective Observation (RO), Abstract Conceptualization (AC), Active Experiment (AE) (Kolb, 1984). Each row of the questionnaire asked respondents to rank the words on a four-point scale: a 4 to the word which best characterizes a participants' learning style, and a 1 to the least characteristic word. Each column corresponded to one of the four learning stages: the sum of the first column gave the scores on concrete experience (CE), the second column gave the scores on reflective observation (RO), the third column gave the scores on abstract conceptualization (AC), and the fourth column gave scores on active experiment (AE). After analyzing the students' scores, students were assigned to different categories of learning preferences with the combination of two different learning stages: diverging, assimilating, conversing, and accommodating (Figure 2).

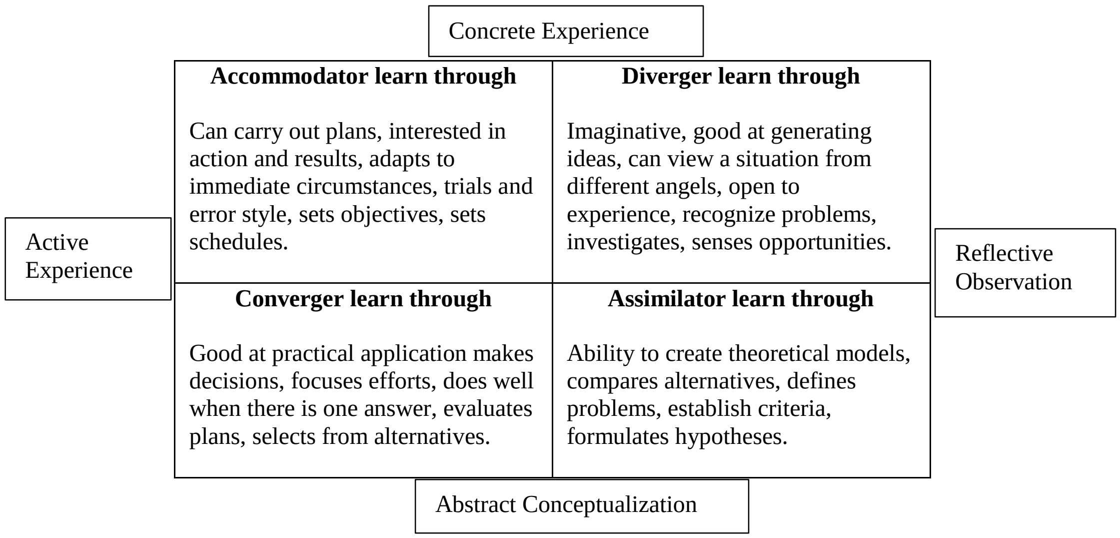


Figure 2. Characteristics of Kolb's Learning Styles (1984)

Note. Diverger combines CE and RO, Assimilator combines AC and RO, Converger combines AC and AE, and Accommodator combines CE and AE.

Diverger learners are based on the combination between Concrete Experience and Reflective Observation. They learn from being with others in groups and by constructive feedback with a wide of information. Assimilator learners are based on the combination between Abstract Conceptualization and Reflective Observation. They learn from logical theories and thinking through the detailed explanation of an expert. Converger is based on the combination between Abstract Conceptualization and Active Experience. They learn by themselves and act independently by using concrete simulations. Lastly, Accommodator learners are based on the combinations between Concrete Experience and Active Experience. They learn from hands-on experiences and by trial and errors.

Gregorc's Thinking Styles (GMS) (Gregorc, 1984). The purpose of Gregorc's thinking styles is to measure how individual think and learn based on the way of perceiving, processing and ordering information. Gregorc's thinking styles model (1984) addresses four different thinking styles (cognition styles): abstract random (AR), concrete random (CR), abstract sequential (AS), and concrete sequential (CS). Each thinking style is defined by specific characteristics that might be compatible with how students learn best. A previous study revealed that one of the thinking styles in Gregorc's model, "abstract sequential (AS)" is compatible with LCM because AS learners learn best with lecture, book/texts, syllabus and guided individual study. "Abstract random (AR)" learners learn best through group discussion and assignments with reflection time, which is compatible with IBL (Bohn etc., 2004). Therefore, Gregorc's model was also chosen for this study because this model potentially had matches with LCM or IBL instructional approaches.

Moreover, Gregorc's model is seen as a bridge between individual personality and cognition by measuring how learners perceive and potentially order new information. In order to measure individual thinking styles, Gregorc created a survey, Gregorc's Thinking Style (GMS). In the GMS, there is the survey of fifteen item to describe participants' four thinking styles: abstract random (AR), concrete random (CR), abstract sequential (AS), and concrete sequential (CS). The survey questionnaires asked participants to mark two words that best describe them in each set. Each column corresponds to one of the four thinking styles: the sum of the first column gave the scores on concrete sequential (CS) the second column gave the scores on abstract sequential (AS), the third column gave the scores on abstract random (AR), and the fourth column gave scores on concrete random (CR). After evaluating the students' scores, students were assigned to different categories depending on the combination of two different thinking styles (Figure 3).

Abstract

Sequential			Random
	Abstract Sequential learn through. Conceptual mind picture, decoding abilities, group work, computer interactive activities and graphics, a presentation based on research, projects, debate or oral reports, and visualization with charts, overheads, graphs, slides, pictures, and models.	**Abstract Random learn through.** Attuned to behavior, interpretive, unstructured, audiovisuals with video, movies, a discussion in groups, art activities such as bulletin board, murals, model making, open-ended activities, and interpretive activities.	
	Concrete Sequential learn through. Step-by-step direction, explicit instruction, ordinal and logical sequence, hands-on activates, formulas, objective test, directed projects, structured reports with specific criteria.	**Concrete Random learn through.** Trial and error, experimental attitude and behavior, class discussion with some structure, field trips, lab work, and experiments, allow multiple/alternative solutions, puzzle, games, simulations.	

Concrete

Figure 3. Characteristics of Gregorc's Thinking Styles (1984)

Note. Abstract Sequential combines Abstract and Sequential, Abstract Random combines Abstract and Random, Concrete Sequential combines Concrete and Sequential, Concrete Random combines Concrete and Random.

Accommodator learners are based on the combination between Abstract and Sequential. They learn from group work, and other visualized tools such as charts, overheads, graphs, slides, pictures, and models. Abstract Random learners are based on the combination between Abstract and Random. They learn from a personalized and flexible environment; emotional sensitivity and healthy relationship with others. Concrete Sequential is based on the combination between Concrete and Sequential. They learn by step-by-step to organize their information. Lastly, Concrete Random learners are based on the combinations between Concrete and Random. They learn from trial and error by being risk-takers who explore unstructured problems and use creative and problem-solving skills.

Mathematics Anxiety Scale. The Abbreviated Mathematics Anxiety Rating Scale (A-MARS) was used in this study to determine students' MA (Alexander, 1989). The A-MARS was a Likert-scale questionnaire including 25 items. Participants were asked to rate the statements on a five-point scale: not at all, a little, a fair amount, much, or very much. Negative statements were weighted from 1 to 5, and positive statements were reversed. The sum of the scores on the questionnaire indicated the MA levels of the student.

Data Collection

For the quantitative methodology, all students completed the Kolb's LSI and Gregorc's GMS instruments at the beginning of the semester, and the A-MARS instrument at both the beginning and the end of the semester. For the qualitative methodology, the researcher conducted site visits one time to each class and collected field notes about the class at large. The researcher also collected any blank classwork, lecture slides, activities, or pictures that the researcher took. This allowed the researcher to ensure the similarity of instruction across the five LCM courses and across the five IBL courses, but also to investigate any potentially qualitative differences of import. Finally, a written questionnaire (created by the researcher) was administered to 28 students, 16 of whom were in LCM, and another 12 of whom were in IBL. The researcher selected the students who voluntarily agreed to participate in the written questionnaire at the end of the semester. This provided additional qualitative data for the students with different learning and thinking styles in each LCM and IBL course, allowing for further investigation of particular students experiences in each course as they might relate to their levels of MA.

Table 2. Participants in a written questionnaire in two different teaching approaches

MAT 56	LCM	IBL
Number of students (n = 28)	16	12

In order to answer the first research question, the A-MARS scores for students in each of the different classes-LCM_1, LCM_2, LCM_3, LCM_4, LCM_5, IBL_1, IBL_2, IBL_3, IBL_4, and IBL_5- at the beginning and end of the semester were used to measure the average MA levels from the each pre-and post-survey over a fifteen-week semester. A linear mixed model was used to compare the differences between the two instructional models (LCM and IBL) with the independent variables of the average MA levels from the pre-survey and the type of instruction. The researcher used a statistical test to determine whether there is any significant difference in the average MA levels from the post-survey of the students in each of the ten classes. Presuming LCM_1, LCM_2, LCM_3, LCM_4, and LCM_5 to have similar results, and IBL_1, IBL_2, IBL_3, IBL_4, and IBL_5 to have similar results, the researcher compared the average MA levels between pre-and post-survey across the two instructional models, LCM and IBL, to determine whether any differences existed.

For the second research question, Kolb's Learning Style Inventory (LSI) and Gregorc's Thinking Style (GMS) were administered at the beginning of the semester. Based on results of the LSI and GMS, students were assigned to one of the four types of learning styles: diverger, assimilator converger, accommodator, and K-flexible defined by Kolb; they were also assigned one of the four types of thinking styles: concrete sequential, concrete random, abstract random, abstract sequential, and G-flexible defined by Gregorc. The researcher ran a linear mixed model to compare students' MA levels in two different instructional model (LCM and IBL) for different learning and thinking styles (Kolb's and Gregorc's). The dependent variable was measured: the average MA levels from the post-survey as measured by the A-MARS. With the linear mixed mode, the researcher determined whether learning and thinking styles across Kolb's and

Gregorc's models were significantly different between the student in the LCM classes and the students in the IBL classes over the semester.

In order to answer the third research question, the written questionnaires of the twenty-eight participating students were analyzed using grounded theory (Strauss & Corbin, 1990); i) finding repeating keywords and phrases, ii) grouping the keyword and phrase based on the emergent themes, and iii) theorizing the relationship of the generated themes. The written questionnaire consisted of eight items, and questions were organized into four themes related to MA: the factor of MA (item 1), instructor's teaching style in reducing or decreasing their MA (item 2 to 4), and their preferred teaching style with MA (item 5 to 7) by sorting the data. The questionnaires were administered to collect data about students' attitudes toward mathematics, their reasons to have MA, and their preferred instructional styles. The results of these surveys informed students' reactions of their instructional styles to determine whether there were any influences on MA levels as related to instructional models (LCM and IBL) throughout the semester.

CHAPTER II

LITERATURE REVIEW

In Chapter II, the researcher elaborates on three main bodies of literature and seeks to understand how teachers' different instruction and students' learning styles influence MA with the relevant literature: the background of MA, learning theories of instructional methods, and individual difference with learning styles. Specifically, this study focuses on teaching instruction and MA to understand the gap between low performance in the developmental mathematics courses and college students' individual preference in learning mathematics. However, relatively few studies have been conducted around relationship between individual learning styles and MA through different teaching styles. Thus, this current study seeks to fill this gap in the literature. The purposes of this review is to establish a theoretical framework that functions as a foundation for understanding the context in which the current study is situated, to further reveal the need for this research, and to provide a basis for methodology decisions. Since this present study focuses on the relationship between individual learning and thinking styles and its relation to MA levels in different instructional classrooms, Kolb's and Gregorc's models are included to gain a more complete understanding of the relationships. Moreover, as the current study attempts to provide greater perception into the relationship between learning and thinking styles and individual MA levels, one of the foci of this review is to recognize the unique findings of previous research that has been conducted using Kolb's and Gregorc's models.

Mathematics Anxiety

In recent years, there has been increasing attention to mathematics anxiety (MA) in higher education. Individually, many students in community colleges struggle either to pass the mathematics courses required for their associate's degree or to transfer to a 4-year institution (Andrew & Brown, 2015). Among first and second year undergraduate students, about 29% in public 4-years college and 41% in public 2-year community college enroll in remedial mathematics course taking, which are not credit-bearing courses (Skomsvold, 2014). In addition, about 68 % of the students who entered in public 2-year community colleges took at least one remedial mathematics course during their undergraduate career (Radford & Horn 2012). These statistics show that many students lack preparedness for college-level mathematics and their lack of knowledge and the inability to understand mathematics concept frequently cultivate anxiety. As a results, many educators and researchers have attended to the relationships between mathematics anxiety and low academic performance. Therefore, diverse intervention programs, instructional strategies and curricula have been implemented to prevent students from struggling in college mathematics courses.

Anxiety in a Mathematics Classroom

In general, anxiety is defined as an emotion characterized by feelings of tension, nervousness, and worry and associated with physical change (Freud, 1926). In mathematics classroom, mathematics anxiety (MA) is described as "a feeling of tension, apprehension, or fear that interferes with mathematics performance" (Ashcraft, 2001, p. 1). For example, a student who has MA might have feelings of discomfort and worry that arise from working with mathematics topics that prevent one from effectively solving a mathematics problem. According to Alexander and Martray's (1989) work, there are three sub-scales of MA: Mathematics Test

Anxiety, Numerical Task Anxiety, and Mathematics Course Anxiety. Mathematics Test Anxiety is related to anticipation, completion and the results of mathematics tests. Numerical Task Anxiety refers to real-life situations involving numbers, quantitative reasoning skills, and completing arithmetic calculations. For example, calculating the tips as a percentage, understanding mathematical operations in everyday situations, and making critical financial decisions such as mortgages or loans, and monthly payments. Mathematics Course Anxiety is described as the difficulty in understanding mathematical concepts or theories in a mathematics course. The students who have MA might have panic attacks, helplessness, paralysis and mental disorganization when they are asked to solve mathematics problems in class (Tobias, 1980). Those students with MA have muscle tension, tight shoulders, dry mouth, cold sweat, and increased or irregular heartbeat as well as incoherent thinking, inability to recall material studied, negative self-talk, and feelings of failure or worthlessness in the mathematics classroom. These symptoms of MA can limit the working capacity that is needed to compute quantitative problems, and it can lead students to forget and lose their self-confidence (Tobias, 1993). Having a lack of confidence in mathematics classrooms and a negative attitude towards mathematics can also cause low academic performance (Ashcraft, 2002; Hembree, 1999; Ma, 2004).

Mathematics Anxiety and Yerkes-Dodson Law

Researchers (Dreger & Aiken, 1957) have long studied the relationship between MA and student performance and indicated that MA could be regarded as a significant factor in determining students' achievement (Brown et al., 2008; Morris & Liebert, 1967). Many studies reveal that MA is closely related to poor academic performance as well as associated with negative attitudes toward mathematics (Hembree, 1990). The Yerkes-Dodson Law (Yerkes & Dodson, 1908) provides a unifying theory explaining the interaction between MA and performance. Based on the law, an inverted U-curve implies moderate levels of stimulation. In Figure 4, when performance levels are manageable, increased arousal can help improve student performance, but only up to a certain point. Increasing anxiety and arousal levels could help focus motivation and attention on the task. When performance levels are challenging, too high of arousal levels could be problematic, making it difficult to focus on the task. Excessive anxiety can impair the ability to remember information. In other words, the degree of arousal can affect performance task. Both low and high levels of arousal anxiety lead to low performance, and a moderate level of anxiety results in optimal performance in a task (Yerkes & Dodson, 1908).

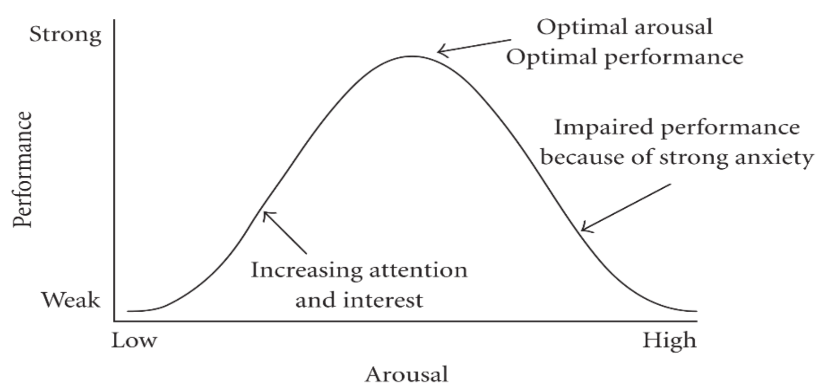


Figure 4. Yerkes-Dodson Law between Performance and Levels of Arousal

The law suggests that too high or too low of MA might affect students' academic performance in education. According to Hembree (1990), increased anxiety can lead to mathematics avoidance. Although there are no apparent causes of MA, the consequences of MA include low academic performance in mathematics, avoidance of mathematics classrooms, and low-entrance rates of mathematics majors in college and mathematics-related jobs.

Factors of Mathematics Anxiety

There are a variety of factors that contribute to MA, such as instruction, environmental influence or curriculum, as well as individual reasons such as language, cultural barriers, different cognitive processing, or lack of mathematics skills. MA can be related to personality type, a negative attitude toward mathematics, experience in learning mathematics, instructor behavior, lack of confidence, cognitive ability, public examination, parents, peer group, relevance and school experiences (Bursal & Paznokas, 2006). These variables correlate with MA and can be classified into three different categories: individuals, teachers, and society (Figure 5). In each category, there are several contributing factors. All factors are important, and are interlinked.

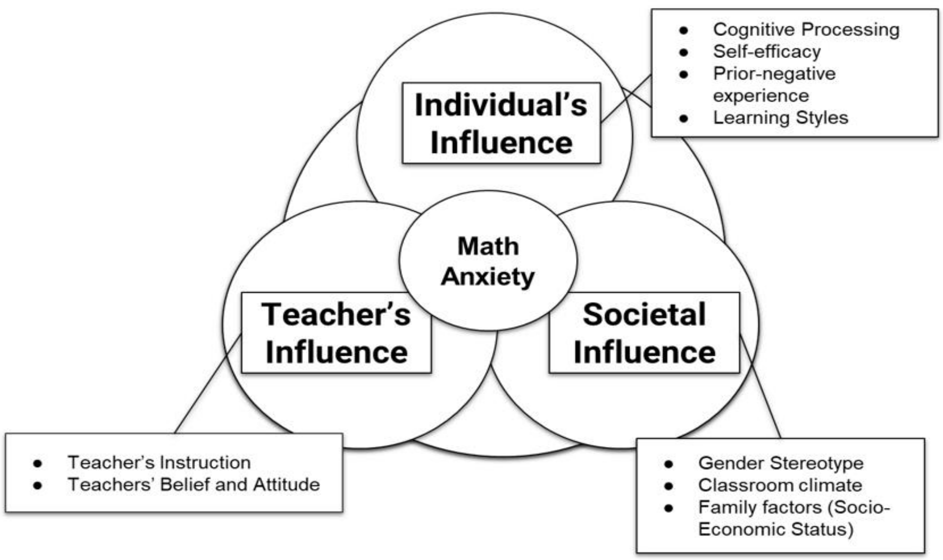


Figure 5. The factors of mathematics anxiety and the contributing factors under individual, teacher and societal influences

Individual's Influence on Mathematics Anxiety. Since MA is a learning condition that happens to some people when faced with a mathematical problem, positive experiences and feelings toward mathematics give students a good perception about mathematics, and vice versa. Many studies found that mathematical self-concept and MA are reciprocally related, and the individual's emotional factor has been the highest factor related to MA (Wahid et at, 2013;

Wondimu et at, 2012). Cognitive processing, self-efficacy and prior experiences in mathematics play an important part of the individual influence on MA.

Cognitive Processing. MA can be different based on an individual's cognitive processing. Cognitive processing refers to, "Directed at achieving a goal when no solution method is obvious to the problem solver" (p. 287). Cognitive processing in learning acquires knowledge through experience, senses, attitudes, and study. In cognitive processing, there are different styles that each of person processes their thinking. For example, Curry (1981) mentioned that cognitive styles are habitual modes of processing information which develop slowly and experientially, are not easily modified, and are distinct from intellectual or cognitive ability. This implies that cognitive styles belong to those deeply rooted individual differences commonly classified as personality difference (Curry, 1981, p. 51). Therefore, an individual with a given cognitive processing may have a wide range of MA levels in response to different tasks and situations. Specifically, under memory capability, many researchers (Engle, 2002; Miyake & Shah, 1999) found that short-term memory is related to low performance. For instance, students who succeed in mathematics are easily able to compute, transmit and manipulate in problem-solving at the same time with high levels of working memory and cognitive processing.

Self-efficacy. The second factor of MA under the individual influence is self-efficacy. There is some evidence that students' cognitive, affective, psychological, motivational, and environmental factors that affect their mathematics performance (Chang & Beilock, 2016). Mathematics self-efficacy is stated as an individual's belief or perception with respect to his or her abilities in mathematics (Bandura, 1997). In general, emotional factors have been an important topic in mathematics performance with mathematics anxiety (Dowker, Sarkar & Looi, 2016; Miller & Bichsel, 2004). In recent studies, self-efficacy has been considered an essential part in the topic of MA, and there is a positive correlation between students' academic success and self-efficacy. Many researchers (Bandura, 1997; McMullan, Jones, & Lea, 2012; Pajare & Graham, 1999) note that strong self-efficacy enables students to engage in mathematics with more effort, time, and persistence. For instance, if a student has a higher level of self-efficacy, he or she tends to construct his or her own beliefs about the capability to perform and persist in pursuing mathematics. Therefore, there is a positive correlation between students' success and mathematics self-efficacy, as well as a negative correlation between student success and mathematics anxiety.

Prior Negative Experience. The third factor of MA under individual influences is prior-negative experience. Since anxiety itself is a feeling of tension as well as several physical symptoms that cause nervousness, fear, and worry, students' prior experience in learning mathematics during their elementary and secondary schooling can be considered as an essential factor to understand how individuals begin to develop MA. Students who have had negative experiences learning mathematics often are faced with mathematics phobia and, as a result, most of them have difficulties in learning various concepts because they feel they are unable to do the mathematics. For example, when students find an incorrect answer, they may feel embarrassed. This may cause them to fall behind in their mathematics classes, which can lead to low test scores and encourage them to give up on learning mathematics. Negative experiences in elementary school are one of the most common causes of MA (Newstead, 1995; Tobias, 1978; Stodolsky, 1985). These embarrassing experiences and low confidence as children can cause MA to increase as they get older. Many adult learners report that having had a negative experience in mathematics affected their mathematics education (Tobias, 1993). With less confidence and exposure to doing mathematics practice, students then avoid learning mathematics, and they are unprepared for their future mathematics courses (Ashcraft, 2001).

Teachers' Influence on Mathematics Anxiety. Many studies investigate how different instructional strategies affect students' MA and their achievements in the mathematics classroom (Boaler, 2008; Brahier, 2013; Harper & Daanc, 1998). In previous research, students' MA was caused by the teacher's instruction, specifically the pace and emphasis on memorization in the lesson (Harper & Daanc, 1998). Teachers' varied instruction in mathematics classrooms including active learning, presenting exciting lessons, and other facilitating class activities leads students to reduce their MA. With these various instructions, students tend to have more interest in learning mathematics if they enjoy the learning activities and if the curriculum connects to their lives.

Teachers' Instruction. Many scholars have found that teachers' instructional methods can be an important influence on student learning in mathematics (Brady & Bowd, 2005; Darling-Hammond, 2004; Hembree, 1990). For example, the instructional practice based on behaviorism and constructivism can impact different levels of MA. According to behaviorist learning theories, a teacher's practice in mathematics would be consistent with direct instruction, memorization and less conceptual understanding of mathematics procedures (Berman, 2003; Latterell, 2005). This type of teacher-centered demonstration in mathematics classrooms can facilitate student failure and MA (Berman, 2003; Boaler, 2008; Laterell, 2005). Instructional practices under behaviorism tend to include one-size-fits-all instruction, rote learning, note taking without a focus on conceptual understanding, and problems with singular (not multiple) solutions, which increase the negative relations between MA and academic performance.

Student-centered instructional practice in the mathematics classroom could be different from a teacher-centered approach under behaviorism. An open-ended inquiry teaching style, discussion, engagement, participation, and collaboration between teacher and students can impact MA differently.

According to studies (Chapline & Newman, 1984), MA in students can also be caused by teachers' verbal and nonverbal expressions and teachers' active participation and communication during the classroom such as caring about students' request for help. For example, having more positive verbal and non-verbal communication is productive for teaching mathematics, in contrast to giving direct guidance. Teachers' poor engagement and their lack of dedication in helping students can also increase students' levels of MA, sometimes more than the content of the mathematics itself (Fiore, 1999; Jackson & Leffingwell, 1999). Regarding classroom structure, if a teacher demonstrates clear goals and standards, or classroom procedures, there is a correlation between mastery, classroom structure, and positive outcomes such as high self-efficacy and positive affect and behaviors (Anderman, 1999; Wolters, 2004). Therefore, MA is connected not only to individual influences but also to instructional influences such as classroom patterns, and a teacher's instructional strategies.

Teachers' Beliefs and Attitudes. The second factor of MA is teachers' beliefs and attitudes that are under the teachers control. According to educational psychologist Aiken (1957), the attitude of teachers toward mathematics have influenced their students' attitudes, and also teachers' teaching styles affect students' mathematics knowledge and skills. Since teachers have a central role for students, their attitudes, beliefs, and ability to teach influences students' levels of MA and performance. For instance, many teachers uphold the negative stereotype that males are superior to females in mathematics (Jackson & Leffingwell, 1999). In this case, teachers' beliefs and attitudes around gender differences might reduce particular populations of students' mathematics performance. Romberg and Kaput (1999) state, "If teachers believe that mathematics is useful, it seems reasonable to assume that they will work harder to ensure that their learner learns mathematics" (p. 174). In the related literature on learners' attitudes toward mathematics, teachers' beliefs influence the way they teach and talk about mathematics to the learners, and these attitudes then affect learners' mathematics achievement. In recent studies (e.g., Furinghetti & Pehkonen, 2002), studies about teachers' beliefs and attitudes have grown considerably, and many researchers strongly agree that beliefs play a significant role in mathematics teaching and learning, and the learning outcomes in mathematics are associated with teachers' beliefs and attitude (Beswick, 2005a; Cooney, 2001).

Societal Influence on Mathematics Anxiety. Not only does MA come from individuals' and teachers' influence, but its development is also tied to societal factors, where students can develop poor results in terms of learning mathematics. Many studies suggest that there is the relationship between socio-economic status and the classroom climate on MA (Adimora et al., 2015). These environmental factors could include negative experiences in the classroom or family factors. Since the classroom climate influences students' intelligence, social relationships, and emotions, there are connections between students' MA and societal influence. Socio-economic status (SES) and gender stereotypes are discussed in this section as societal influences that contribute to MA.

Socio-Economic Status (SES). According to the program for International Student Assessment (PISA, 2016), across the organization for economic cooperation and development

(OECD) countries, 14% of the variation in mathematics achievement is explained by students' levels of MA. In this research, the variations among the students with the highest mathematics performance are explained by their socioeconomic status. There is a strong relationship between social and economic background status and increased opportunity for success in mathematics. Many other scholars (Wang et al., 2014) have found that socioeconomic factors are critical components in understanding how MA originates, and how it relates to students' achievement in mathematics. Lareau and Annette (2003) observed that low-income minority students and parents with less education have shown to be strong predictors of a range of physical and mental health issues. Since the parent's role varies according to their different social classes, this affects how they engage with their children's education on a day-to-day basis. Middle-class parents not only spend more money on their primary-school-aged children, enabling them to attend a variety of extra classes such as high levels of mathematics, science, technology, dance, drama, music, art, and poetry, but also can provide educational advantages for their children such as additional tutoring. With different learning opportunities based on SES, low SES students can have lower performance on word problems and algebraic reasoning in mathematics test and are more likely to drop out of school (Eamon et al., 2005; Hochschild, 2003; Vukovi, Roberts & Green, 2013). These results do not mean that the rich are born smart; rather, this only implies that in more affluent families, children tend to have more opportunities that foster their intellectual development (Darling, 2004). In particular, middle-class parents can affect the content and delivery of the curriculum with extra money, so that their children benefit from, for example, being in an honors track. They may also be able to influence which teachers their children have. In this way, it is possible for parents to mobilize their social, cultural, and economic capital in order to exercise their voice over educational issues. As a result, low income and minority students from society tend to have lower-performance in mathematics in part due to their SES.

Gender Stereotype. In general, a stereotype can be defined as a fixed image of behavior shared by people, community and society. There are a variety of gender stereotypes when a person is expected to act based on their gender. Many studies reveal that many teachers have gender stereotypes in mathematics classrooms. Since teachers' perspectives reflect their school’s, community’s and society's perceptions, these gender stereotypes in education between boys and girls lead to misperceptions in the mathematics classroom as well. In education, there are certain types of behaviors that are categorized as masculine or feminine. For example, such stereotypes include that girls have successful academic results because of their work ethic whereas boys have successful academic results because they are gifted. Even though boys and girls have the same mathematics performance and behaviors, teachers tend to perceive that the boys are better than girls are at mathematics. Furthermore, girls who believe their mathematics intelligence is fixed and unchangeable tend to have lower performance in mathematics than girls who believe their mathematics skills are malleable (Burkley et al., 2010). With these social determinants, including parents’ socio-economic status and math-gender stereotypes, MA interacts with students’ self-efficacy, GPA, attitude toward mathematics, and students’ performance at large.

Influence of Learning Theories on Teaching Instructions

Because of the diverse factors associated with MA, many studies have explored the causes of MA and their influences on relationships with individuals, teachers, and society (Gurganus, 2007; Latterell, 2005; Vinson, 2001; Young, Loveridge, et al., 2006). Specifically, some researchers (Farrell, 2006; Shields, 2005) have argued that MA may stem from teaching methods based on a rule-based methodology that leads students to have negative feelings about learning mathematics. As a result, teachers, parents, are administrators are looking for efficient teaching instruction and strategies in the mathematics classroom to reduce MA. Teaching methods and several versions of instruction have changed to improve students' learning. In particular, psychological theories and educational practices have advanced in teaching and learning; instructional methods are derived from learning theories. A learning theory explains how learning occurs, and an instructional theory defines a better way to help people learn (Reigeluth, 1999). In particular, an instructional theory offers explicit guidance on how to help people learn and develop. Instructional theory has been influenced by at least three types of learning theories: (1) behaviorism (learning as response acquisition), (2) constructivism (learning as knowledge construction), and (3) individual difference (learning as different learning styles). There is a great amount of research that addresses how teachers can influence students' learning experiences through their instructional theory (Brady & Bowd, 2005; Hembree, 1990). Especially in learning mathematics, students can have different levels of MA depending on teachers' teaching styles (Furner & Duffy, 2002).

Teacher-Centered Instruction under Behaviorism. Under Thorndike's behaviorism, many researchers (Freilberg & Lamb, 2009) believed that the behaviorist theory would influence a teachers' active role in teacher-centered instruction. Teacher-centered instruction is an approach to teaching that places the teacher as the director of learning and is mainly accomplished by lecture, students' repetitive practice of basic skills, and constructive feedback (Martorella, 1991). The researchers mention, "In the traditional model of classroom management, discipline is teacher-directed based on behaviorism” (Freilberg & Lamb, 2009, p. 99). This suggests that behaviorists believe that there are rewards that cause students to bring predetermined consequences; therefore, teachers can control students based on teacher-centered instruction. In this perspective, the teacher plays a dominant role in the classroom by taking control and evaluating learning. For example, teachers directly communicate or transfer their knowledge and skills to the learner. As a result, the learners do not have enough opportunity to reflect on their learning processes, and they are simply following or doing what a teacher tells them. According to Skinner (1976), "education is to present that student with the appropriate repertoire of behavioral responses to specific stimuli and to reinforce those responses through an effective reinforcement schedule" (p. 161). One of the strategies of teacher-centered instruction is the lecture method, which has been associated with behaviorism.

Lecture Method in Mathematics Classroom. Lecture is one of the most commonly used instructional methods in higher education. Nearly 80% of all U.S. college classrooms reported using some form of lecture to teach students (Cashin, 1990). The lecture method has been considered both problematic and programmatic as a mode of teaching and learning**.** In recent decades, other teaching strategies have been widely developed, but the lecture method is still used as an essential means of communicating information between an instructor and students. The lecture method is defined as when an instructor continuously gives an oral presentation of information and ideas during the class (Behr, 1988). An instructor gives a lecture based on the instructor’s own reading, research, experiences and interpretations of his or her own insights (Sandhu et al., 2012). In Sandhu’s (2012) argument, lecturing is a single method of teaching between an instructor and students that does not involve significant student participation.

In a traditional mathematics classroom, a teacher uses the lecture method by addressing the content in a lecture form, showing some typical problems, and rarely performing demonstrations while presenting the content. Meanwhile, students listen to the teacher, take notes, and rarely ask questions. Since there is a lack of interaction between the instructor and students, students are considered passive learners who have fewer opportunities to engage in active learning. These characteristics of the lecture method lead behaviorists to believe that students master mathematics terms and solve procedures through their memorization of information and drill and practice tutorials before problem-based learning takes place (Shield, 2005) (Table 3.)

Table 3. Characteristics of teacher and students in lecture method

Characteristics	Lecture Method Classroom under Behaviorism
Role of Teacher	- Teachers talk in front of students, and students listen to the teacher's lesson. - Teachers control information based on teacher-centered. - Lecture method is useful in big classes. - Teachers are not sure if the students are concentrating on their lesson, and Understanding the concept taught to them by the teacher.
Role of Learners	- Students are passive learners and listeners. - Students listen and take notes as an independent learner. - Students do not have the opportunities to correct their misunderstanding during the class. - Students are engaged with low-cognitive demand.

According to researchers (Sandhu et al., 2012), teachers in a lecture model have more algorithmic steps in problem-solving, ignore cognitive processing and quantitative reasoning, and focus on conveying teacher-centered practice with worksheets with practice problems, which can contribute to developing MA. This happens because teachers focus on the understanding of rule and procedures in mathematics. Direct instruction, repetitions, drills, and memorization become a critical component in teaching and learning mathematics. In a mathematics classroom under the lecture method, students tend to be taught procedural content, and not the conceptual content, with the following strategies: demonstration, direct instruction, drill and practice, and note taking.

Demonstration. The instructor emphasizes telling, explaining, and showing. He or she focuses on telling how the concepts work or operate. For example, an instructor demonstrates how to operate with fractions, or how to solve arithmetic equations on the board. Based on the explanation, students understand how to solve problems.

Direct Instruction. The instructor guides the procedures of problem-solving directly and simplifies the questions and difficult concepts so that students observe what they are asked to do.

Drill and Practice. The instructor explains a task, and the learner practices it. There is less participation and engagement among students. For example, in order to master the multiplication table, students are asked to make a calculation based on memorization; students practice skills for tests.

Note Taking. The instructor asks students to write or summarize the lecture based on students' understanding of content. Students do not have much time to share their thoughts and tend to become passive learners by listening to the lecture, taking notes or focusing on the instructor’s voice.

Lecture Method and Mathematics Anxiety. In general, there is a considerable amount of research (e.g., Cashin, 1990; Jones 2005; McKeachie et al., 1999) that indicates some positive effects and outcomes of the lecture method. First, McKeachie (1999) compared the lecture method with other forms of instruction and found that the lecture method can be more efficient than other methods of teaching as a means of transmitting knowledge. However, other scholars mention that the lecture method is relatively ineffective for teaching and learning skills and for inspiring in a subject (Bligh, 2000; French, Sarah, & Gregor, 2016). Since the lecture method refers to passive or didactic instruction based on a behaviorist theory of learning, students are motivated by rewards and punishment of the grades assigned by teachers (Brown, 2003). Specifically, “Low cognitive demand tasks in lecture classrooms involve stating facts, following known procedures, and solving routine problems” (Van De Walle, Karp, & Bay-Williams, 2012, p. 36). These tasks require minimum thinking or cognitive analysis, and focus instead on single, concrete answers that are solved using prior knowledge. Low demand tasks “lead to one type of opportunity for student thinking" (Stein & Smith, 1998, p. 269). These low-level demand tasks can be broken down into two different types in LCM: i) memorization, and ii) procedures without connections (Stein & Smith, 1998). Memorization tasks involve pulling facts and formulas from prior memory in order to solve the equation. These tasks are quick and sometimes timed, and can lead to an inability to use procedures to find an answer. That is, this type of low cognitive demand task requires no connections to the meaning of the information that is being learned (Smith & Stein, 1998). Moreover, unrelated tasks in the procedure tend to reinforce students following a specific procedure from prior learning. For example, most tasks in LCM require little thinking of how to complete the task. As a result, students do not know why and how a procedure is done in problem-solving. These tasks concentrate on only getting the correct answer without explanation or mathematical understanding (Smith & Stein, 1998).

Moreover, in the lecture method, the classroom is managed in an orderly fashion. It implies that students become followers while teachers are directing all of the classroom activities. Students only answer when an instructor poses a question. It shows that the teacher retains full control of the classroom and its activities. In this process, an instructor conveys the one-way lesson to students through direct instruction by narrating, demonstrating, presenting, and explaining on the subject that they have mastered. As a result, it enables an instructor to control students' works and behaviors, and students tend to have more anxiety as passive learners who superficially listen to the lecture and participate less in class.

Lastly, the lecture method in the traditional mathematics classroom does not support students' understanding of mathematics concepts, problem-solving skills, and motivation (Chiapetta, 1973). These issues have encouraged educators to develop alternative teaching methods. According to Vandervoort (1983), in the lecture method, teachers usually do not discuss how students build knowledge through memorization. Since students are not motivated to discover concepts by themselves, the lecture method tends to cause students to have anxiety in learning and understanding new concepts. Because of this, students learn based on memorization skills, and they do not have an opportunity to use other necessary process skills (Ray, 1961), which can cause their MA to increase (Figure 6).

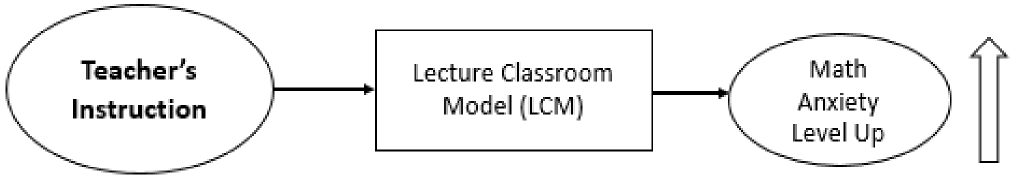


Figure 6. The influence of Lecture Classroom Model (LCM) on students' mathematics anxiety.

Student-Centered Instruction under Constructivism. Constructivism is a paradigm that, in education, refers to learning as being an active and constructive process, in which directed questions help students find weaknesses in their thinking. Constructivism also emphasizes the importance of the active involvement of learners in constructing knowledge for themselves. Constructivist pedagogy places a greater emphasis on student-centered instruction. According to Collins and O'Brien (2003), student-centered instruction is an instructional approach in which students influence the content, activities, materials, and pace of learning. Student-centered classroom encourages students to set goals for themselves so that students can build both their self-confidence and their learning skills. Students are able to explore the content in various ways that requires students to participate in the mathematics, while instructors are guiding on the side.

The constructivist approach allows students to be actively engaged in the content and develop their own explanation of procedures and practice. The teacher becomes a facilitator of learning in this approach in contrast to being central to the learning that is occurring. The teacher focuses on guiding students by asking questions that lead students to develop their own conclusions on the subject. Direct instruction is useful for teaching the order of operations, new procedures and revising those procedures that have been taught previously. However, inquiry is used more for problem solving questions where students are using prior background to work their way to a resolution. These interactions between teachers and students give students opportunities to share different aspects of problems solving. According to many researchers (Siemon, et al., 2011), the constructivist approach envisions learners actively interacting with other students, teachers and environment physically, socially, and psychologically. Each student is an active agent in the construction of learning based on the prior knowledge and experience they have. One of the strategies of student-centered teaching is inquiry-based learning that has been associated with constructivism. In particular, inquiry-based learning has been revealed to see whether there are influences on MA.

Inquiry-Based Learning in Mathematics Classroom. Inquiry-based learning (IBL) approach is used as a means to develop information-processing and problem-solving skills. This approach includes active learning, based on a student-centered environment where the teacher has the role of learning facilitator. Applying Piaget's constructivism in mathematics, students using their own algorithms for the multiplication of integers is better than a standard one given by their teacher. That is, in the IBL classroom, students construct knowledge through their own experiences and inquiries, and as a result, they have a variety of ways of problem solving (Table 4).

Table 4. Characteristics of teacher and students in inquiry-based learning classroom

Characteristics	Inquiry-based Learning Classroom (IBL) under Constructivism
Role of Teacher	- Teachers guide students to engage in their learning. - Teachers are facilitator to convey knowledge to students based on student-centered. - Teachers believe that IBL is effective in small classes. - Teacher are able to see whether the students understand the concept by observing their engagement, communication and participation during the class.
Role of Learners	- Students are active learners. - Students work with peers or in a group. - Students do have the opportunities to correct their misunderstanding within the class. - Students are engaged with high-cognitive demand

Another psychologist, Kamii (2007) stated that in an IBL, there are plenty of opportunities for movement and active observation; the students are certainly talking very much and arguing back and forth. Their opinions will be asked about, and the kids will challenge each other. In that study, the researcher observed that students were actively engaged with the materials, and they enjoyed discovering their own rules in problem solving. In particular, IBL simulates the process by which students discover knowledge and emphasize their experiences. Teachers who use IBL include activities such as: 1) designing a question, 2) materializing a plausible explanation based on evidence gathered, 3) sharing students' ideas and different perspective in problem solving, and 4) reflecting ideas in the learning process.

Moreover, in the IBL classroom, instructors tend to have the role of facilitators and not lecturers (Bauersfeld, 1995). Instead of listening to the teacher's presentation, students become active learners where students struggle to discover, construct, and develop their own ideas in problem solving. Many researchers (Swafford, Findell, & Kilpatrick, 2001) have demonstrated that giving students enough time to think is an essential part of constructing diverse strategies in solving problems. In *Adding It Up*, they wrote, "more than just a means to produce answers, computation is increasingly seen as a window on the deep structure of the number system" (p. 182). If a teacher allows students to use their own algorithms, students are able to develop the use of number-oriented, flexible algorithms that offer them a rich view of the numbers. For example, in the solving algorithm, 49 x 7, a simple invented strategy might involve 40 x 7 = 280 and 9 x 7 = 63. The sum of 280 and 63 is 343. For most of students, this can easily be done mentally, or even with some recording, in much less time than writing the 7 below the 49, recording the 3 from 49 and carrying the 4. Then 4 x 7 is 28 and 2 is 34. To see the answer, the 34 is recorded next to the 3. Invented strategies for addition and subtraction nearly always become mental strategies. Flexible methods are often considered a faster and more useful way than the traditional algorithms. The students who discover a strategy for computing, or who adopt a strategy from a peer, are also engaged intimately in the process of inventing an algorithmic procedure. From this example, in the IBL classroom, knowledge is actively constructed by students' engagements. As a result, students come to realize that procedures for difficult tasks can be devised, and many develop a confidence in their own ability to do so. This development of procedure is a process that traditionally has been hidden. In general, there are no clear components of Inquiry-based learning, however, there are three characteristics that many teachers agree on: Bloom's Taxonomy, asking questions, and the teacher's role as a facilitator.

*Bloom's Taxonomy***.** The first component of IBL is Bloom's Taxonomy (Bloom, et al, 1956). In IBL teachers ask questions that come from higher levels of Bloom's Taxonomy. Higher order thinking enables students to develop critical thinking skills during inquiry activities. Teachers are able to establish the learning environment and expectations by classifying the questions based on the Bloom's Taxonomy (Table 5). With higher order thinking skills in IBL, students benefit from ample opportunity to develop creative and divergent thinking skills and to discover what they know, what they don't know, how much a learner links their prior knowledge with new concepts, or misconceptions that interfere with their understanding. Using the senses to explore their learning in Bloom's Taxonomy, students becomes questioners. In IBL, class discussion and guided questioning are a critical part of learning.

Table 5. Bloom's Taxonomy (Bloom, et al, 1956)

Knowledge	Students are able to arrange, define, duplicate, label, list, memorize, name, order, recognize, relate, recall, repeat, and reproduce state. They also remember or retrieve previous learning concept.
Comprehension	Students are able to classify, describe, discuss, explain, express, identify, indicate, locate, recognize, report, restate, review, select, and translate. They understand the interpretation of instructions and problem in one’s own words.
Application	Students are able to apply, choose, demonstrate, dramatize, employ, illustrate, interpret, operate, practice, schedule, sketch, solve, use, and write. They use a concept in a new situation or apply what they learned into novel situations.
Analysis	Students are able to analyze, appraise, calculate, categorize, compare, contrast, criticize, differentiate, discriminate, distinguish, examine, experiment, question, and test. They distinguish between facts and inferences so that its problem-solving structure can be understood
Synthesis	Students are able to arrange, assemble, collect, compose, construct, create, design, develop, formulate, manage, organize, plan, prepare, propose, set up, and write. They find pattern from diverse elements or build a generalized structure by emphasizing on creating a new meaning or structure.
Evaluation:	Students are able to appraise, argue, assess, attach, choose compare, defend estimate, judge, predict, rate, core, select, support, value, and evaluate. They make judgments about the value of concept or ideas

Asking questions that motivates students. IBL involves questions that are interesting and motivates to students (Swan et al., 2012). Students are more engaged when they are asked to write down their learning, discuss it with peers, and participate in classroom discussions. By guiding students through meaningful questions, students are allowed to learn how to solve problems in a supportive environment with the help of their peers and their teacher. Teachers ask questions to students and figure out what students want to know, and what they do not know about the concept. The following examples are IBL questions: “What do you want to know about the topic? What kinds of resources might help you to approach this problem? How is this relevant to the questions? and What is the main point?" More specifically, there are five different types of questions that are used in IBL classrooms (Wolf, 1987) (Table 6). Then, students explore their questions, find information and explain how they understand the concept and solve problems. Discovering the solutions through the teachers' questions fosters self-motivation, active participation, and collaboration with peers.

Table 6. Types of questions in inquiry-based learning classroom (Wolf, 1987)

Inferenced Questions	Students are asked to go beyond the immediately available information. Teachers ask students to look for clues, examine them and fill the missing information if they have a role in the question. For example, "How do you make a conclusion by reading this article? and "How did the author feel about the character in this book?"
Interpretation Questions.	Students are asked to predict what results may occur in a given situation. Teachers ask students to use their prior knowledge of situations and new information. For example, "You found that there are more tobacco ads on the TV ads than radio. What does that illustrate about TV ads?"
Transfer Questions	Students are asked to use their knowledge and apply it to new situations. Teachers ask students to expand their knowledge and ideas. For instance, "We found many patterns in Geometric concepts. Let's look at art work, and see what patterns you find there?"
Questions about Hypotheses.	Students are asked to predict outcomes and discover new knowledge. For example, "Are stress and health related? Does the levels of stress affect levels of health?"
Reflective Questions	Students are asked to go over the beliefs that they have and the evidence that supports them. Teachers asked students to back into investigation. "How do we really know that there are negative relationships between stress and health?", and "How do we know that the articles in the New York Times telling the truth?"

Teacher as a Facilitator. The third component of IBL is the teacher as a facilitator, or delegator. In IBL, the teacher uses several constructivist characteristics: asks questions to students, hands-off support, provides guidelines and creates the environment for the learner to arrive at his or her own conclusions, and has class discourse with the learners (Rhodes & Bellamy, 1999). The teacher focuses on "how students come to know" and less on "what they know." Teachers help students be engaged in the construction of knowledge through inquiries. In IBL, encouraging students is an important aspect because it enables students to persevere long enough to construct in-depth knowledge and learning. With teachers' support and guidance, students are able to reflect their learning. Moreover, teachers manage students as a team so that the team members help other members stay focused and make progress together. In this more passive role, teachers help the learner to develop his or her own understanding of the content while students are active and engaged in their learning.

Inquiry-Based Learning and Mathematics Anxiety. In general, students learn best when they take an active role and practice what they have learned (Smart & Csapo, 2007). When active discussion is used, the classroom is found to be more effective in relation to the following: (1) retention of knowledge after the end of a course, (2) transfer of knowledge to a new situation, (3) problem solving and thinking, and (4) an improved attitude. Specifically, in IBL, "High cognitive demand tasks involve making connections, analyzing information, and drawing conclusions" (Smith & Stein, 1998). High-level tasks require students to think abstractly and make connections to mathematical concepts.

> "When completing higher demanding tasks students are engaged in a productive struggle, which challenges them to make connections to concepts and to other relevant knowledge." (Van De Walle, Karp & Bay-Williams, 2012, p.37).

High-level tasks can be separated into two types in IBL: procedures with connections and doing mathematics. Procedures with connections places emphasis on the use of procedures, in order to improve students' deeper level of understanding of mathematical concepts and ideas. For example, in a task in IBL, students develop the meaning of mathematical ideas by the use of multiple representations (visual diagrams, manipulates, symbols, etc.), cooperative learning, questioning during the discussion and other technology in the mathematics classroom. Students are able to engage with conceptual ideas, meaning the task triggers the procedure that is needed to complete the task, and develop understanding (Smith & Stein, 1998, p.348). Doing mathematics is the second type of higher-level tasks. These tasks require multifaceted thinking. Doing mathematics requires students to comprehend and understand mathematical connections. These tasks allow students to monitor their own process of thinking, while using applicable knowledge to work through the task. In order to complete the task in IBL students must analyze the task, which requires considerable cognitive effort. The tasks in IBL, however, may cause some apprehension of behalf of the students, because the teacher does not provide a specific list of procedures to solve the problem (Smith & Stein, 1998, p.348).

Through the activities in IBL, including highly-cognitively demanding tasks, peer group activities, collaboration, written mathematics journals, and role activities, students are able to develop critical thinking skills, and ownership over their own learning, and to achieve their goals. By working with peers, students understand the importance of asking good questions. Teachers foster curiosity for students' learning instead of giving direct lectures and solutions so that students have deeper understandings that go beyond memorizing facts and content. John Dewey found that inquiry could improve education because students are able to use their natural activity and curiosity when learning about a new concept (Dewey, 2008; Vandervoort, 1983). With these reasons, many researchers argued that IBL reduces students' MA (Lubinski & Otto, 2004; Sloan, 2010) (Figure 7).

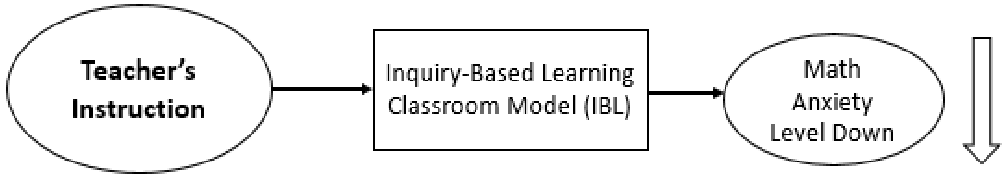


Figure 7. The influence of inquiry-based learning classroom model on students' mathematics anxiety.

However, in IBL, teachers might face difficulties in maintaining students' interests, because students are supposed to discover, have curiosity, and be involved with peers to derive appropriate results on their own (Bencze, 2009). For some challenging mathematics concepts, there might be limitations to students using the inquiry method (Spronken, 2018). Even though students have opportunities to share their different perspectives in problem solving with peers, there are still some students who need lecture sessions where they can understand the concept first from a teacher. For some students LCM may tend to induce their anxiety, but for others, IBL may tend to cause anxiety, due to individual differences and learning styles. IBL can be challenging since students in such classrooms tend to lack prior-knowledge and the self-discipline needed to solve problems on their own. They may struggle and give up learning mathematics with high levels of anxiety. Therefore, these limitations suggest that ignoring students' different learning and thinking styles may be part of the problem with respect to MA. In addition, since the teacher works only as a facilitator, this condition may keep a teacher from monitoring all students during IBL instruction. It implies that some students naturally discuss and work with others by focusing on the same goal; however, other students might stay away from the instruction by focusing on just chatting with other students or increasing their MA. Further research is thus needed to examine the influence of learning styles under individual difference on MA (Figure 8).

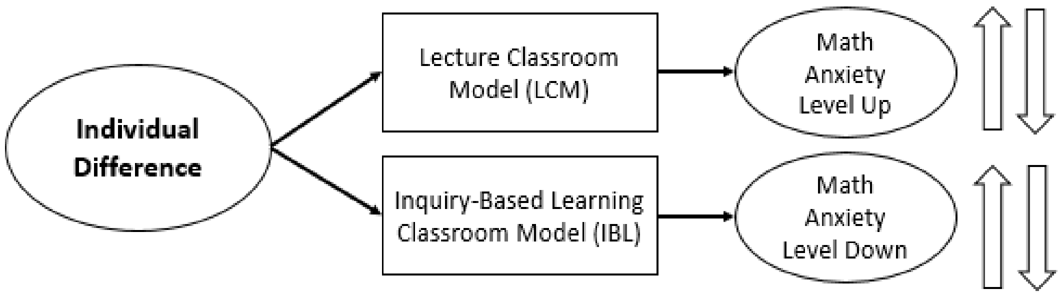


Figure 8. The influence of individual difference on mathematics anxiety.

Note. No matter in either a Lecture Classroom Model or an Inquiry-based Learning Classroom Model students' mathematics anxiety can be different.

Individual Difference

Another body of literature has suggested that ignoring students' individual difference and their different learning styles may be part of the problem with respect to MA. According to Carter (1959), individual differences stand for the variations among individuals in regard to a single characteristic or a number of characteristics. Individual differences are associated with the personality of learner as well as their learning style, learning speed, and their needs and interests as a learner. According to Skehan (1989), age, aptitude, motivation, general intelligence, sensory preferences, and sociocultural conditions are the examples of the factors affecting the way learners react to classroom instruction. Due to individual difference, students can spend different amounts of time completing the same assignment. Given this perspective, many modern psychologists found that cognitive abilities of individual difference are related to network-level characteristics of the brain and the availability and development of brain function (Newman & Just, 2005; Prat et al., 2007). Comparatively, in education, the individual differences of students have influenced teachers' instructional planning as a mean of offering students a better education

(Reynolds et al., 1987). As a result, individual difference affects choices made by both teachers and learners, as both attempt to lessen the development of MA. As such, there have been efforts to modify teaching styles based on students' individual characteristics, e.g., differentiation. As well, the individual's preferential method of learning can also influence the level of MA. Therefore, teachers should consider students' individual differences, and their learning styles in particular.

Learning Styles and Mathematics Anxiety

Learning styles, in general, are widely used to describe how individuals have specific learning preferences in order to achieve effective learning (Coffield, Moseley, Hall & Ecclestone, 2004; Pashler & Bjork, 2008). Learning styles can include students' preferred ways of thinking, relationship with others, and classroom environment preference (Grasha, 1990). Using individual differences, several studies have been conducted about the relationship between MA and learning styles (Esa & Mohamed, 2017; McCoy, 1992). McCoy (1992), which revealed that MA was most prevalent among tactile kinesthetic learners, while others (Nel & Nel, 2013) found that MA was positively correlated with auditory preference with respect to students' learning styles. Since there has been less research done in the area of MA and learning styles, this study seeks to determine if there is a correlation between MA and learning styles in two different teaching models. This study investigates the relationship between the general concept of a learning style, which is defined as "*an individual's preferred method of learning under the individual difference*," and the general concept of teaching instruction, which is conceptualized as "*a teacher's different methodology and the environment created.*"

Moreover, cognitive thinking styles are an individual's preferred way of gathering, processing, and evaluating information (Hayes & Allinson, 1998). In the learning process, students are able to link new information to prior knowledge and interpret the information into the mental mode that guides his or her action. In cognitive learning strategies, instructors focus on how the learner processes his or her knowledge and support the learner's development of internal procedures that enable them to perform complex tasks. The interactions between MA and cognitive thinking styles can also affect learners' high or low anxiety level depending on the instructor's teaching strategies. For example, environmental causes such different classroom models, the amount of class work, or a teacher's instruction are associated with experiences of MA. At the same time, individual differences such as innate characteristics, different learning and thinking styles and learning preferences affect the experiences in the mathematics classroom (Rubinsten & Tannock, 2010). Each individual can be classified according to their cognitive characteristics based on single- or multi-dimensional scales. Specifically, this study examines the correlation between individual's learning and thinking styles, as defined by Kolb (1984) and Gregorc (1984) and MA (Figure 9).

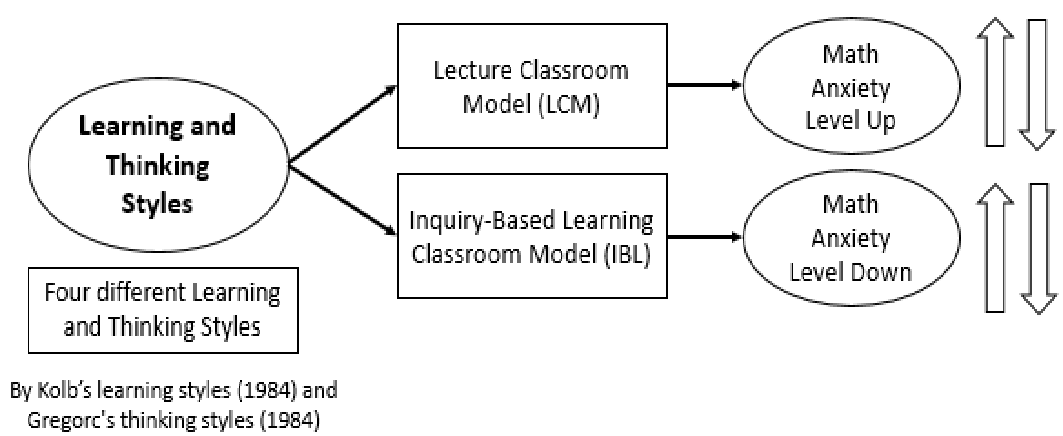


Figure 9. The influence of learning and thinking styles defined by Kolb (1984) and Gregorc (1984) on mathematics anxiety.

Note. This model suggests that in either Lecture Classroom Model or Inquiry-based Learning Classroom Model, students' mathematics anxiety can be increased or decreased depending on their learning and thinking styles.

Teaching Strategy with Learning Styles

Based on students' different learning styles, teachers can act as guides to children's learning and adapt the curriculum to their individual needs and developmental levels. For example, in a classroom, instructors can utilize different curriculum or instructional styles by understanding students' different cognitive development and learning styles and assigning tasks for which they are prepared. The students can then be given tasks that are tailored to their developmental level and are motivating. Furthermore, teachers can provide students with learning opportunities that enable them to advance through each developmental stage. This can be achieved by creating disequilibrium. Teachers can begin by maintaining a proper balance between actively guiding the student and allowing opportunities for them to explore things on their own to learn through discovery. Teachers also can consider the process of learning rather than the product of learning. Differentiated instruction means teaching students with different needs in the way(s) they learn best, and has been presented as the solution to all sorts of problems a student can throw at his or her teachers.

In differentiated instruction, teachers consistently use a variety of instructional approaches to modify content, processes, and/or products in response to a learner's readiness and interests (Tomlinson, 2001). That is, it is a classroom where learners are provided with equal opportunity to learn, but are not expected to learn the same curriculum in the same way at the same time. The intent of differentiating instruction is to individualize instruction for each student's growth and success by meeting each student where they are and assisting in the learning process. However, for students with MA, the task of differentiating each lesson may require accessing additional resources, planning for small-group interaction, and modifying lessons during delivery (Tomlinson, 2001). Additional supports are needed for teachers to give each student the attention and individualized instruction that they need. Students with physical disabilities, behavioral difficulties, learning disabilities, MA, and cultural and linguistic diversity require a complex support system. Each has specific difficulties that prevent them from being successful without significant supports to access and to demonstrate their understanding of the subject matter (Lawrence-Brown, 2000). As a result, not appropriately differentiating instruction may be part of the problem with respect to MA. Many teachers agree that the concept of differentiated instruction is a productive way to help meet the needs of different levels of students through individualized learning. However, although many teachers do consider their students' preferred learning styles, they are not sure which teaching strategies and styles need to be instructed in the classroom (Sharp, Bowker, & Byrne, 2008), and which further develop student's MA. Some problems are further created when a teacher uses only one instructional style. Even though differentiated instruction affects students' individual difference positively or negatively, there is not enough research to support the benefits of differentiated instruction with respect to learning style. Therefore, in this study, students' effective learning is defined based on not only teaching styles but also the preferred strategies that belong to learners. Individual learning preference is next highlighted using David Kolb (1984) and Anthony Gregorc's (1984) theoretical perspective.

Learning Style Model

Learning style has been a central and theoretical concept in both education and psychology for many decades. A variety of learning style models and disciplines have been studied, and the area of mathematics anxiety (MA) and learning styles has been studied extensively and separately. However, few studies show the relationship between the MA and the compatibility between learning styles and teaching styles. In order to understand the relationship between MA and learning styles, Kolb's (1984) and Gregorc's (1984) work frames this study.

Kolb's Learning Styles

By understanding the differences in how students take in and process information in mathematics, teachers need to balance instruction for all learning styles. Some researchers found that students' learning styles could cause MA (Esa & Mohamed, 2017; Grasha, 1996). However, it was found that the levels of MA could also be diminished by understanding students' learning styles. In order to understand students' learning styles, teachers need to provide a variety of educational practices to reach all students. Teachers need to consider MA and implement suitable instruction in order to help their students overcome MA. Depending on teachers' instruction, students can reduce their anxiety around mathematics.

David Kolb (1984) introduced the learning style model, which developed a learning style inventory. Kolb's empirical learning theory is two-fold: a four-stage cycle of learning and four different individual learning styles. According to Kolb, "Learning is the process by which knowledge is created through the change of experience" (p. 38). Learning is associated with acquiring abstract concepts that can be flexibly applied to a wide variety of scopes. That is, the stimulus for the development of new concepts in Kolb's theory is provided by new experiences.

Kolb's Experiential Learning Cycle. Kolb's experiential learning is represented by a four stage learning cycle. According to Kolb (1984; 1985), learning is a four-stage process involving concrete experience (CE), reflective observation (RO), abstract conceptualization (AC), and active experimentation (AE) (Figure 10).

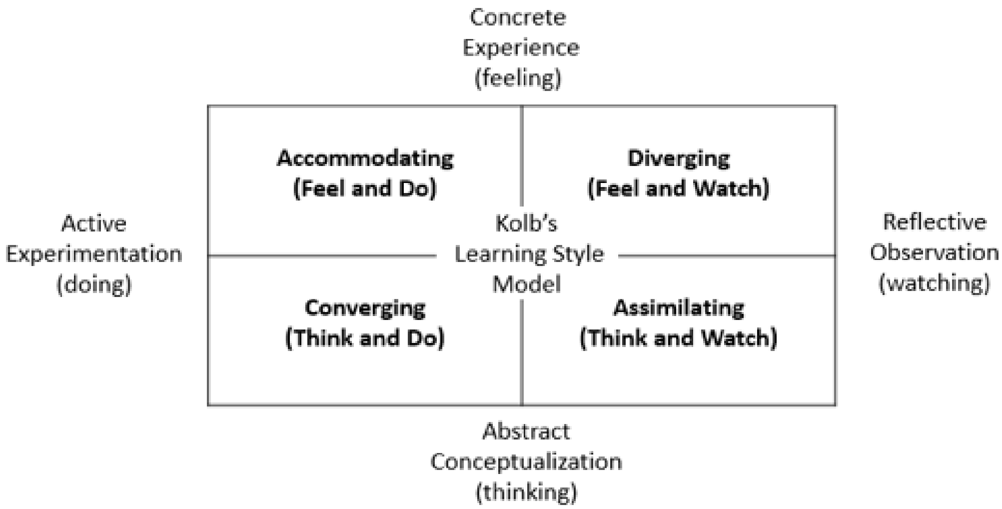


Figure 10. Kolb's Experiential Learning Styles.
Note. Brouwer et al. 2015

For instance, concrete experience (CE) focuses on experiencing and dealing with immediate human situations in a personal way. The characteristics of CE include complexities of the present as opposed to theories and generalizations. For instance, students have an experience that involves emotion, perceptions, intellect and action. Reflective observation (RO) refers to the meaning of ideas and situations by watching and listening to the situations. Students are able to reflect on an experience to identify the principles. Abstract conceptualization (AC) focuses on using critical thinking, logic, and concepts as opposed to feeling. One of the characteristics of AC is to use systematic planning, manipulation of abstract symbols and quantitative analysis. Therefore, students are able to identify the principles in an experience. Lastly, active experimentation (AE) focuses on influencing people and changing situations, and the applications of AE is to use theories to solve problems and make decisions. For example, students seek more opportunities to repeat the experience to perfect learning. These preferences result in a classification of personal learning styles. In Kolb's theory, students are able to have different CE, AE, AC and RO depending on their learning cycle, and they will become an effective learner if they practice all four styles. In recent studies (Saeed & Majic, 2012), there was a positive relationship between MA and concrete experiential learning style while there was a negative relationship between MA and abstract conceptualization learning style. Additionally, there was a result regarding the investigation of the relationship between MA and learning styles according to educational achievement, MA and abstract conceptual learning style had a negative relationship.

Kolb's Learning Styles. Kolb's Learning Styles (1984) presents four distinct learning styles based on four levels of the learning cycle. At that time, many people believed that there was a single learning style. However, Kolb argued that various factors such as social environment, educational experience, and basic individual cognitive level affect individual's preferred learning style. He introduced that there is the impact of various factors on students' learning styles by representing the combination of at least two preferred styles. The learning style preferences were defined as two pairs or two separate choices that individual's create. For example, Kolb explains there are vertical and horizontal continuum axes, which are called the processing continuum for the horizontal line and perception continuum for the vertical line. The processing continuum is how individual's approach a task, and the perception continuum is representative of how individual's think or feel in response to a task. Kolb's model provides a combination of four preferred learning styles: Diverging, Assimilating, Converging and Accommodating (Table 7).

Table 7. The characteristics of Kolb's learning styles

Kolb's Learning Styles (1984)	Characteristics
Diverging	Divergers are the combination of CE and RO. They are usually producing alternative solutions to problems, and tend to work in humanities and liberal arts.
Assimilating	Assimilators are the combination of AC and RO. They have the capability to create theories by being a logical thinker. They like to concentrate on concepts and concrete ideas rather than opinion. They tend to work in basic science and mathematics.
Converging	Convergers are the combination of AC and AE. They are good at making a decision and good problem solvers, and tend to work in the physical science and engineering.
Accommodating	Accommodators are the combination of CE and AE. They like to plan and complete the goas by having new experience and change. They also like to work with people, and tend to major in business, social science or other practical fields. It implies that learning styles are not fixed based on individual personality trains, but it has patterns of behaviors that was affected by individual's environment and experiences.

Gregorc's Thinking Styles Model (1984). Many scholars have reported that every person has different cognitive thinking styles that influence an individual's learning and preferred teaching methods (Driscoll, 1994; Fischer & Fischer, 1979; Messick, 1984). The idea of a thinking style is that an individual has a different way of reasoning that influences her or his modes of cognition and behavioral expression (Vernon, 1973). Over the years, various theories of psychology have contributed to the field of cognitive thinking styles. There have been different streams of cognitive styles, and this study focused on the cognitive styles that are understood to be an individual's preferred and habitual approach to process information – primarily as a learner. Specifically, Anthony Gregorc's (1984) thinking styles model describes how an individual learner perceives, processes, and orders information based on four different thinking styles. Gregorc defines cognitive styles as a set of visible behaviors that represent an individuals' underlying mental strength and ability. He observes that cognition is bipolar: there are two ends of a spectrum in the assimilation of how humans process and acquire knowledge and information. His observation led to the conclusion that dualities can be relevant to perceiving, ordering, processing and relating of information. Specifically, he defines that the perceptual dualities are concrete and abstract, the ordering dualities are sequential and random, the processing dualities are deductive and inductive, and the relating dualities are separative and associative. After several years of observing the dualities, the thinking styles (Gregorc, 1984) derived from two modes of learning: perceptual and thinking processing modes to establish learning preferences for the individual based on thinking styles (Figure 11)

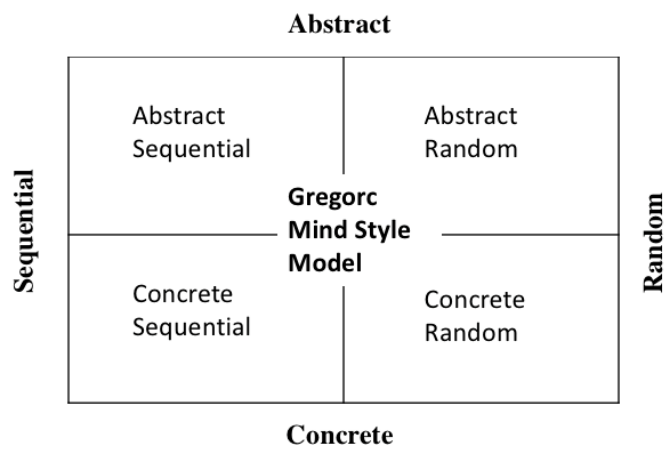


Figure 11. Gregorc's Thinking Style Model

Moreover, Gregorc's thinking styles model is similar in manner to Kolb's (1984) learning styles based on both x and y-axes. A perceiving continuum ranges from abstract to concrete, and an ordering continuum ranges from random to sequential. The combination of these continuums develops the four different learning preferences based on thinking styles: 1) Concrete Sequential, 2) Abstract Sequential, 3) Concrete Random, and 4) Abstract Random (Table 8).

Table 8. The characteristics of Gregorc's thinking styles

Gregorc's Thinking Styles (1984)	Characteristics
Concrete Sequential (CS)	The concrete sequential learner prefers to present their information sequentially with concrete facts and data. They prefer to have hands-on experiences and to learn step-by-step with detailed instruction. They learn best with organized lesson plans presentations and instructional format.
Concrete Random (CR)	The concrete random learner is a spontaneous learner who learns very quickly and assimilates backs and knowledge. This learner relies heavily on their intuition in order to get to some kind of conclusion. They prefer a trial and error methodology to understand their learning process. They tend not to seek for a lot of input from instructor guides.
Abstract sequential (AS)	The abstract sequential learner quickly learns through a variety of means including decoding verbal and written and even visuals. Visuals is a significant characteristic to AS learner and they require learning environment which are organized and formatted and even filled with vital and valid knowledge.
Abstract Random (AR)	The abstract random learner acquires information in an unsystematic way with little or no formal outline or direction. They are flexible in their learning environment, and they tend to have a time to reflect and ponder in order to organize the information into a pattern or a schema which makes sense to them.

From the point of view of this research, each student has a different learning and thinking styles and this study investigates whether a particular teaching style influences individual students' MA.

Rationale for Using Kolb's Learning Style and Gregorc's Thinking Styles.

In general, there are a number of studies about the relationship between learning and thinking styles and mathematics. Various scholars have differing schema for learning styles including, Kolb's learning styles (1984), Peter Honey and Alan Mumford's model (1986), Neil

Fleming's VAR modalities (1992), Reid's learning styles (1998), Anthony Gregorc's model (1984), and others in the education literature. First, Neil Fleming's VARK model (1992) use different learning types such as Visual, Kinesthetic, Reading, Writing, and Auditory. The VARK models are easy to measure and to apply to teaching models. Specifically, high achievers in mathematics tend to have auditory learning styles (Shahrill et al., 2013). However, some psychologists argue that the VARK models are more of learning abilities or preferences rather than learning styles (Willingham et al., 2007). Secondly, there is another learning style by Reid (1998) that he calls "perceptual learning styles" as the changes "among learners in using one or more senses to understand, organize, and retain experience" (p. 89). That is, Reid's model has internally based characteristics that are used by learners to transmit new information and figure out how to learn best. As a result, learners prefer to boost their confidence and consequently their performance. However, learners do not pay attention to the influence of teaching instruction because they believe that their learning styles are fixed even if they encounter different teaching styles and different classroom environments (Yassin, 2012).

In contrast to Reid's learning styles, Eilisha (2007) asserted that learning styles can change as a consistent pattern of behavior that is influenced by individual personalities, cultural backgrounds and learning strategies in schools and societies. This model focuses on learning strategies rather than individual learning styles. Dunn (2000) described learning styles as the way each learner absorbs and retains information and skills, added upon a learning modalities approach. Dunn's learning styles foster talents where the learner's strengths lie; at the same time, the learners who do not have their strengths can be disrupted in learning when they find their weakness. This is because Dunn believed that environmental, emotional, sociological, and physical elements contribute to the learning environment that has considerable ecological validity (Dunn, 2000).

Justification of Using Kolb's Model. The above listed learning styles were built upon David Kolb's model (1984) of learning styles. Kolb first developed the model of learning styles, and then the learning style model was reproduced by Honey and Mumford as a replica of Kolb's experiential learning theory (Ayalp & Özdemir, 2016). Due to the depth of the research over many years, the emotional and psychological aspects of Kolb's experiential learning theory and Gregorc's thinking styles is compatible with the Lecture Classroom Model (LCM) and Inquiry-Based Lecture Classroom Model (IBL) used in this study. For example, one of the learning styles in Kolb's model, "assimilating," is estimated to be compatible with LCM because assimilating learners prefer to think things through based on clear and concise explanations. A previous study showed that assimilators respond better to the information presented to them in a systematic method (Felder & Brent, 2005). "Assimilating" learners give teachers opportunities to incorporate a format including lectures and multimedia presentations. On the other hand, the "diverging" learning style from Kolb's model is estimated to be compatible with IBL because the learner prefers to work in groups by listening with an open thinking to receive constructive feedback.

Another previous study showed that "diverging" learners respond best to group projects and all types of discussion (Tulbure, 2012). It shows that they learn through exploration toward discovery rather than lecturing facts or testing knowledge through memorization. Moreover, in Gregorc's model, "abstract sequential" learners are estimated to be compatible with LCM because they learn best with lecture, book/texts, syllabus and guided individual study. On the other hand, "abstract random" learners learn best through group discussion and assignments with reflection time (Gregorc & Butler, 1984; Kaplan & Kies, 1993), which is compatible with IBL. Because the learning and thinking styles from the Kolb's and Gregorc's models are most easily matched with either LCM or IBL style, these models are chosen for this present study over other learning styles.

Moreover, Kolb's model has been used in a wide variety of educational settings, including mathematics education, higher education, professional education, career education, adult education and other areas of education for a better connection between individual learning styles and educational choice (Duff, 2004). Specifically, Kolb's learning styles have been translated into mathematical learning styles (Knisley, 2002). According to his study (Knisley, 2002), in a mathematical context, concrete and reflective learning styles corresponds to allegorizer who is able to distinguish the new mathematical concept from known mathematical concepts; concrete and active learning styles corresponds to integrator who want to compare and contrast their previous knowledge in problem-solving; abstract and reflective learning styles corresponds to analyzer who prefer to think logically with detailed descriptions, and; abstract and active learning styles corresponds to synthesizer who solve problems by developing individual strategies. Thus, it has been suggested the ideal teaching styles would include each stage of mathematical learning styles (Jensen & Wood, 2000; Kinsely, 2002) for the teacher of mathematics (Table 9).

Table 9. Kolb's Learning Styles in Mathematical Context

Kolb's Learning Styles	Equivalent Mathematical Styles	Role of Mathematics Teacher
Concrete, Reflective	Allegorizer	Storyteller
Concrete, Active	Integrator	A facilitator and motivator
Abstract, Reflective	Analyzer	A source of information
Abstract, Active	Synthesizer	A coach

Moreover, in a teleconferencing course at a community college, Dille and Mezack (1991) found that there were correlations between Kolb's model and students' preferences in the courses.

Furthermore, Kolb (1984) stated that for the learner to be effective in adapting knowledge or skill, he or she has to engage in four stages: 1) concrete experience (CE), 2) reflective observation (RO), 3) abstract conceptualization (AC), and 4) active experience (AE). Later on, Baasanjav (2013) stated that, in an effective learning process, a learner finds out the dialectics between CE and AC, and between observation and action. In this learning process, "experiential learning theory considers learning as a cycle that begins with experiences, continues with reflection and later leads to action that becomes a concrete experience for reflection" (Ayalp & Ozdemir 2016, p. 366). It implies in mathematical development that individuals develop their knowledge by personal experiences and inquiries. A learner is then able to observe their experiences with other viewpoints by having opinions or theory with its additional reconstruction in a stage Kolb calls abstract conceptualization. Then, with the individual learner's abstract conceptualization, a learner operates its new concrete experiences. In this process, Kolb emphasizes emotion and senses as a significant catalyst and moving forces in the learning process (Baasanjav, 2013). Kolb's Learning Style Inventory (LSI-II) (Kolb, 1985a) has been judged psychometrically reliable (Terry, 2001).

Research by Smith and Kolb (1986) claimed that the four preferred learning styles, concrete experience (CE), reflective observation (RO), abstract conceptualization (AC), and active experience (AE) had a Cronbach alpha rating of 0.82, 0.73, 0.83, and 0.78 respectively. In reporting the reliability of scores from the LSI 3.1, Kolb & Kolb (2005) concentrate on the internal consistency with respect to Cronbach's alpha (1951). Kolb and Kolb (2005) addressed internal consistency of scores through alpha values reported in seven different studies. For instance, the study used an online sample of 5,023 participants, and reported alpha values ranged between .77 and .84 for the four subscales (AC, CE, AE, and RO) of Kolb's LSI 3.1. The study revealed that the alpha values were .82 for abstractness over concreteness (AC-CE) and .82 for action over reflection (AE-RO) (Kolb & Kolb 2005). In another study, the study was conducted with a sample of 221 participants, and found the alpha values ranged between .78 and .84 for the same four subscales of the KLSI 3.1 (Kayes, 2005). These mentioned findings of a Cronbach alpha rating show that the reliability among AC, CE, AE, and RO is high. The validity of the LSI 3 was shown to be high through research that used correlation coefficients and factor analyses (Kolb & Kolb, 2005). In order to enhance the justification of the use of Kolb's model in MA, the author (Terry, 2001) states,

"Learning styles are related to patterns of individual thoughts, beliefs, attitudes, and behaviors. Learning style theorists thus typically focus on the affective (emotion/feeling), cognitive (recognition knowledge) and behavioral (physical skills) components to develop the four-stage cycle of the learning process. David A Kolb used these components to develop the four-stage cycle of learning that comprises his Experiential Learning Model" (Terry, 2001, p. 3).

Terry also argued that Kolb's model includes the affective domain, which is appropriate for considering relationships to MA (personal communication, Nov 29, 2017). In the present study, MA is being defined as a feeling of tension in solving mathematical problems.

Justification of Using Gregorc's Model. Compared to Kolb's LSI (1984) where there were three domains: affective, behavioral, and cognitive to identify the four-stage cycle of learning styles, Gregorc's thinking styles (1984) developed around the cognitive dimensions, and it has four learning styles: 1) Concrete Sequential, 2) Abstract sequential, 3) Concrete Random, and 4) Abstract Random. Specifically, Gregorc's thinking style instrument is "intuitively appealing” (O’Brien, 1990). In this model, an individual person has content knowledge and the development of intellectual skills is a learning style. That is, Gregorc’s four different thinking styles are characterized differently depending on how an individual recalls or recognizes specific facts and concepts that serve developing intellectual abilities and skills. Thus, Gregorc’s model (1982a) is developed based on how a learner cognitively receives and processes information, and his model is defined as “a lens that we as educators can use to help differentiate instruction to appeal, engage, and facilitate learning for different type of students who have different needs” (p. 2) in education. Specifically, Greogorc’s thinking styles translates learning into the different developmental education practices such as independent assignments, testing, student group presentations, projects, and teacher-led lesson plans (Terry, 2002).

Additionally, Gregorc (1984) reports the reliability and validity of the GSI instrument. In his study, there were 110 adults who tested from 6 hours to 8 weeks apart achieved standardized alphas ranging from .89 (AS) to .93(AR) for 6 hours apart and .91 (CR) to .92 (CS, AS, AR). Other researchers, however, report lower (but acceptable) alpha coefficients (e.g., Joniak & Isaksen, 1988, O’Brien, 1990) ranging from .51 to .64. The reliability of Gregorc’s model is sufficient to investigate the construct validity in terms of its use in the classroom. Many scholars have employed Gregorc’s thinking styles in different settings: high school students (Backes, 1993), post-secondary school students and vocational technical students (Norris, 1998), liberal arts college and university students (Bokoros & Goldstein, 1990, 1992; Kreuze & Payne, 1989; Swearingen, 1998).

CHAPTER III

METHODOLOGY

The present study expresses the interaction between students' learning and thinking styles and two different instructional models in terms of their effect on MA: the lecture classroom model and the inquiry-based learning model. This study was conducted by using both quantitative and qualitative research methods to answer the research questions. The study's data were collected during the spring 2018 semester at an urban community college located in the northeast United States. Ten mathematics instructors from Urban Community College (UCC) (Pseudonym) were coordinated to collect the data during their class sessions. Their students participated in the online survey at the beginning and end of the semester, and the classes were observed once during the semester. The written questionnaire was also administered after the post survey at the end of the semester. Therefore, the data collected from the online pre and post survey, students' written questionnaire, and classroom observation were analyzed to answer the research questions:

1. What is the difference between a lecture classroom model (LCM) and an inquiry-based learning classroom model (IBL) on students' mathematics anxiety levels over a fifteen-week semester of a college-level remedial mathematics course?
2. What is the difference between a lecture classroom model (LCM) and an inquiry-based learning classroom model (IBL) on mathematics anxiety levels for students with different learning and thinking styles (as defined by Kolb's and Gregorc's learning styles) over a fifteen-week semester?

3. What aspects of instructional approaches (LCM and IBL) do students with different learning and thinking styles report as being related to mathematics anxiety?

Research Context

Urban Community College (UCC)

Although the study primarily considers the relationship between the individual and the teacher (instructional approach) as related to mathematics anxiety, societal factors are also important. I provide some details about the research context and participants as a means to situate potentially pertinent societal factors within the study. This study was conducted in spring 2018 at UCC where diverse students - often first-generation college students, from low-income families, minorities, recent immigrants, English language learners, etc. - were registered in a wide variety of vocational, business, health, science, engineering and continuing education field. This population of students are often associated with increased levels of anxiety (including mathematics anxiety) in higher–education settings (Richardson & Skinner, 2000). For instance, many first-generation college students are told that they will not be able to find jobs because they are underprepared in basic reading, writing and mathematics skills to undertake college-level work. The fact that many students are first-generation college students of color with inadequate academic preparation tends to heighten their anxiety about receiving a college education.

With an enrollment of over 26,000 students, the UCC's student demographic is American Indian (0.4 %), Asian (14.5%), Black (31.3 %), Hispanic (41.4 %) and White (12.6 %) in fall 2016. The most updated data from the school website indicates that approximate 15,000 students were female, and approximate 11,000 students were male. In fall 2017, about 18,000 students were registered as full-time, and about 85,000 students were registered as part-time. The UCC requires students to take the mathematics placement test as they enroll. Scores on this test determine what level of mathematics course a student may take. A student must demonstrate proficiency in pre-algebra (arithmetic) and elementary algebra. If students score at least 45 on the placement test in mathematics, have high regents exam scores, SAT scores, or earned BA or BS degree, they can be exempt from taking any remedial courses. In response to students' needs in improving their mathematics skills, the UCC has developed a variety of curricular offerings. In order to provide the best education for its students, UCC has used a free and open source online homework system called WeBWork, designed and developed comprehensive educational resources, including supporting materials, a mathematics lab, and a tutoring center. UCC has amplified the impact on learning mathematics by including small-group tutoring, collaborative learning, student-centered learning, adaptive syllabi, study skills and time management training, peer coaching, problem-centered learning, distributed practice, online homework, virtual manipulatives and modular workshops. Thus, students have been able to receive open educational resources, productive teaching and learning practices, and lessons freely and publicly available. In particular, the mathematics department at UCC made a new project, called Opening Gateways to support students' success in mathematics courses.

In Fall 2017, the mathematics department selected both part- and full-time instructors as fellows to provide intense training for seven days before taking over a classroom in spring 2018. The fellow instructors were requested to attend faculty seminars to learn about active learning strategies, inquiry-based learning, STEM application, flipped classroom, gaming in mathematics instruction, WeBWork, growth mindset, and project presentation for seven days over the fall 2017 semester. After the training sessions, the fellow instructors were expected to use diverse teaching practices focusing on Inquiry-based leaning, utilizing instructional technology and 21st-century teaching and learning strategies and applications in their math classrooms in the following spring semester. Moreover, all fellow instructors were required to teach MAT 56 (intermediate algebra) for their spring 2018 teaching schedule participating the ongoing professional faculty seminar. In this study, the researcher defined the IBL instructors as the UCC's trained fellow instructors of MAT 56, and they and their students were observed during the spring 2018 semester.

Rationale of Choosing MAT 56

For students who are accepted to the college, they are asked to pass UCC's Assessment Test in mathematics. Students who fail to pass the exam are required to take a remedial course. At UCC, where the researcher collected data, the mathematics department provides four remedial mathematics courses: MAT 8 (Basic Mathematics), 12 (Basic Arithmetic and Algebra), 51(Elementary Algebra) and 56 (Intermediate Algebra). Students are assigned to the remedial course that corresponds to their level of mathematics. MAT 56 was chosen for this study because the IBL instructors of MAT 56 were trained for diverse active learning strategies; and because it is the highest level and the last of remedial algebra courses offered at the college. Most of all, increased levels of MA potentially exist in MAT 56 students because there are about to take credit-bearing mathematics courses if they pass MAT 56.

Course Descriptions

MAT 56 is open to students who have completed elementary algebra or its equivalent. It includes such topics as: factoring, solutions of linear and quadratic equations, trigonometric relationships, exponents, logarithms, and the graphs of quadratic equations. Those students who are assigned to MAT 56 meet three times a week for 100 minutes per session, totaling 40 hours of class time for the semester. Students assigned to MAT 56 have test scores that indicate mastery levels in mathematics at least equivalent to MAT 12 course requirements.

Research Design

Study Participants

At the beginning of the semester, 246 students completed the pre-survey where 126 of them were in IBL and 120 were of them were in LCM. During the 15 academic weeks, 29 students in IBL dropped the classes and 32 students in LCM dropped the classes. Thus, this study involved the students (n=185) who were registered for MAT 56 remedial mathematics course at UCC. 88 of them were in a lecture classroom model (LCM), and the remaining 97 were in an inquiry-based classroom model (IBL). This determination was based on the instructors' participation of the IBL training session that the mathematics department held in the fall 2017 semester. That is, the identified IBL-instructor participated in the training sessions, and the other identified LCM-instructors did not participate in the training sessions. The researcher requested an approval of the students' participation in MAT 56 from the ten instructors and the school administrators. Upon the consent of school administrator and instructors, students in MAT 56 became subjects of the study. As a result of the selection process, two hundred sixty-four students participated in the online survey at the beginning and a hundred eighty-five students remained enrolled in the course throughout the duration of the semester and completed the second online survey at the end of the semester. Moreover, twenty-eight students voluntarily participated to complete the online written questionnaire. The participants in the study were not aware which MAT 56 class was LCM and IBL when they registered for the class. The pre-survey at the beginning of the semester revealed the students' demographic information, MA level, and learning and thinking styles as defined by Kolb's and Gregorc's models. The post-survey at the end of the semester measured their MA level again. Students were not aware of their results of either survey.

From the students' demographic information, the sample data were analyzed from the 185 students who completed both the pre and the post survey. Table 10 shows the 185 participants' age, gender, and ethnicity categories. The majority of student participants were in the 18-21 range (69.2%). They are listed in decreasing percentages as follows: 22-25 range (20%), 26-29 range (9%), above 30 range (1%). The gender classification revealed that more females (53%) than males (47%) took the surveys. The ethnicity category showed that the majority of the participants were Hispanic (36%), African America (23%), Asian (22%), others (12%), and White (7%).

Table 10. Demographics of sample with age, gender, and ethnicity

	Age				**Gender**	
Range	18-21	22-25	26-29	Above 30	Female	Male
Total	128	37	17	3	98	87
Percentage	69.2%	20%	9%	1%	53%	47%

	Ethnicity				
	Hispanic	Asian	African America	Others	White
Total	66	43	41	22	13
Percentage	36%	23%	22%	12%	7%

Instruments

The researcher coordinated with each of the ten instructors to collect data using the three survey instruments: The Learning Style Inventory (LSI) by Kolb (1984), Gregorc's Thinking Style (GTS) by Gregorc (1984), and the Abbreviated Version of the Mathematics Anxiety Rating Scale (A-MARS) by Alexander (1989). The learning style inventory by Kolb has twelve questions, Gregorc's thinking style has fifteen questions, and A-MARS has twenty–five questions. These different surveys were used to measure students' different learning and thinking styles and their MA levels. In addition, the pre-survey was designed to elicit students' background information (e.g., gender, race, students' status, etc.). The post-survey consisted of the A-MARS only. The researcher developed the written questionnaire, and administered it to the volunteer students from both LCM and IBL class who agreed to participate in the survey.

Abbreviated Mathematics Anxiety Rating Scale (A-MARS). The Abbreviated-Mathematics Anxiety Rate Scale (A-MARS) (Appendix C) and the original Mathematics Anxiety Rate Scale (MARS) were both found to be multidimensional, identifying MA to deal with mathematics test anxiety, numerical anxiety, and anxiety directly related to mathematics courses. The A-MARS is a Likert-scale questionnaire including 25 items: the first 15 items were related to test anxiety; the next 5 items identify numerical anxiety and the last 5 identify mathematics course anxiety. In terms of reliability and validity, the A-MARS was reported to have an alpha coefficient of .96 for the 15 items associated with mathematics test anxiety, .86 for the 5 items related to numerical task anxiety, and .84 for 5 items related to mathematics course anxiety, positively comparable to the coefficient alpha of .97 for MARS (Rounds & Hendel, 1980; Alexander & Martray, 1989). For this study, a reliability analysis was calculated on the perceived task values scale composing 25 items. Cronbach's alpha showed the questionnaire to reach acceptable reliability α= 0.96. The A-MARS also having Cronbach's alpha of 0.95 for the first 15 items that is related to mathematics test anxiety, 0.95 for the next 5 items related to numerical task anxiety and, 0.89 for the last 5 items related to mathematics course anxiety. All the items appeared to be worthy of retention in this study. The Abbreviated Mathematics Anxiety Rating Scale (A-MARS) was used in this study to determine students' MA by dealing with mathematics test anxiety, numerical anxiety, and anxiety directly related to mathematics courses. Participants were asked to rate the statements on a five-point scale: not at all, a little, a fair amount, much, or very much.

Numerical value is assigned to each response on the scale ranging from 1 to 5. The average of the scores on the questionnaire indicates the MA levels of the student (Appendix C). The highest possible MA level is 5, and the lowest possible MA level is 1.

Learning Style Inventory (LSI) (Kolb, 1984). The Kolb's Learning-Style Inventory (Appendix D) describes individual preferences for the way students learn and how they deal with ideas and day-to-day situations in their life. There were 12 sentences with a choice of endings in the online survey. Students ranked the endings for each according to how well they think each one fits with how they would go about learning something. Students ranked a "4" for the sentence ending that describes how they learn best; down to a "1" for the sentence ending that seems least like the way they learn. An example of a completed sentence set is:

When I learn: "2" I'm happy, "1" I am fast", "3" I am logical, "4" I am careful. (4 = most like you, 3 = second most like you, 2 = third most like you, 1= least like you).

One word in each column corresponds to one of four learning modes: concrete experience (CE: feeling), reflective observation (RO: watching), abstract conceptualization (AC: thinking), and active experimentation (AE: doing). For this study, the four preferred learning styles, CE, RO, AC, and AE had a Cronbach alpha rating of 0.29, 0.52, 0.145, and 0.371 respectively.

Gregorc's Thinking Styles (GTS) (Gregorc, 1984). In order to identify an individual's thinking style, Gregorc created the Gregorc's Thinking Style (GTS) (Appendix E). This test instrument has 15 questionnaires to measure an individual's thinking processes, especially as they relate to learning. It is created to recognize how individuals cognitively receive and process information most efficiently. Each questionnaire contains 4 specific words, and the participants marked two letters of the words that describe them best. An example of one of the set of words: In order to test your own thinking style, read each set of words and mark the two that best describe you: I) imaginative, II) investigative, III) realistic, IV) analytical. After participants completed their marks for the 15 sets, the researcher summed up responses for each column I, II, III, and IV based on the letters of the words that participants chose in the column. Then, the totals of each column were multiplied by 4 (based on Greogorc's instructions). Each column corresponds to one of four learning modes: A) Concrete Sequential, B) Abstract Sequential, C) Concrete Random, and D) Abstract Random. For this study, the four preferred thinking styles, CS, AS, AR and CR had a Cronbach alpha rating of 0.40, 0.36, 0.49, and 0.33 respectively.

Data Collection

The researcher recruited the instructors and professors based on the seminar that the Mathematics Department of UCC held in fall 2017. The fellows in the seminar learned about diverse pedagogical approaches including, Inquiry-Based Learning, Active learning, Flipped Classroom, Gamed-Based learning, and WeBWork (free online homework). Therefore, the instructors in the Inquiry-based learning model classroom (IBL) were recruited based on their experiences and participation in 7 days of professional development. Compared to the trained instructors in IBL, the instructors in lecture-classroom model (LCM) were recruited without the training.

Pre-Survey. The researcher contacted both IBL and LCM-instructors prior to the start the semester asking for the permission to use their students as participants. All chosen instructors responded to the researcher to coordinate the online survey before the start of the semester. During the first week of the semester, the researcher went to class sessions of all ten instructors in order to coordinate collecting student's email addresses from the students who wanted to participate in the online survey. In the first visit, the researcher informed students about the study while asking for their voluntary participation. In the second visit, the participants spent about 20-25 minutes completing the A-MARS questionnaire (Appendix C), Kolb's LSI (Appendix D), Gregorc's GTS (Appendix E), and provided their gender, age, ethnicity, education, and employment status, and email address. The online pre-survey was conducted via the participants' personal computer, cell-phone or school-computer during the class session.

Field Notes. The field notes were conducted during the semester to observe each instructor's teaching style and students' learning behaviors, attitudes toward mathematics, and experiences in both LCM and IBL. The researcher visited all ten LCM and IBL classrooms to determine whether the instructors' teaching styles remained the same or different between LCM and IBL. Five instructors in LCM and the other five instructors in IBL were observed one time during the semester for 60 minutes. In the field notes, the researcher had two parts, descriptive notes and reflective notes (Creswell, 2013). For the descriptive notes, the researcher attempted to document factual data such as date, time, classroom setting, actions, behaviors and conversations during the classroom. For the reflective notes, the researcher recorded personal thoughts, ideas, questions, and concerns that is respond to the descriptive notes in conducting the observation.

Post-survey. At the end of the semester, 15 weeks after the pre-survey, the researcher went to all class sessions to collect the pre-surveys from the beginning of the semester and, with the granted permission, the same students spent 10-20 minutes completing the A-MARS questionnaire only. The online post-survey was conducted via the participants' personal computer, cell-phone or school-computer during the class session.

Written Questionnaire. After the post-survey, the written questionnaire items were given to the participants who voluntarily participated in the survey. This survey (Appendix F) was conducted based on the questions created by the researcher during the class session. The written questionnaire helped the participants to share their feelings about MA, instructional approaches, etc., in further detail.

Data Analysis

In order to answer the first research question, the A-MARS scores for students in each of the different classes-LCM_1, LCM_2, LCM_3, LCM_4, LCM_5, IBL_1, IBL_2, IBL_3, IBL_4, and IBL_5- at the beginning and end of the semester were used to measure the average levels of MA before and after the semester. A linear mixed model was performed to compare the differences between two instructional models (LCM and IBL) with the independent variables of the average MA levels from pre-survey and the type of instruction. With the linear mixed model, the researcher determined whether there was any significant difference in the average MA levels from the post-survey of the students in two instructional models. That is, the researcher compared the changes in MA across the two instructional models, LCM and IBL to determine whether any differences existed.

For the second research question, the Learning Style Inventory (LSI) and Gregorc's Thinking Style (GTS) were administered at the beginning of the semester. Students were assigned to one of the five types of learning and thinking styles in each Kolb's (diverger, converger, assimilator, accommodator, and K-flexible) and Gregorc's (concrete sequential, concrete random, abstract sequential, abstract random, and G-flexible) models. A linear mixed model was performed to compare the differences between two classroom models (LCM and IBL) with the independent variables of the average MA levels form pre-survey, the type of instruction, and students' learning and thinking styles (defined by Kolb's and Gregorc's). The researcher used a statistical test to determine whether there were any significant differences in the average MA levels from the post-survey of the students with different learning and thinking styles in two instructional models. That is, the researcher determined which of the five types of learning and thinking styles was significantly different between the student in the LCM classes and the students in the IBL classes over the semester.

In order to answer the third research question, the written questionnaires of the twenty-eight participating students were analyzed based on a qualitative approach. According to Creswell (2013), a qualitative approach should not only summarize and review the responses from participants but also analyze, describe, code, interpret and construct them. The qualitative approach includes participants' claims to knowledge, narrative design, and open-ended interviewing (Creswell, 2013). In this study, the researcher gave and collected open-ended questionnaires which allowed participants to describe their experiences. In order to analyze the data, the researcher used the basic principles of the grounded theory method (Strauss & Corbin, 1990), which is "inductively derived from the study of the phenomena it represents" (Strauss & Corbin, 1990. p 23). Charmaz (2006) explains the process of grounded theory:

"We gather data, compare them, remain open to all possible theoretical understanding of the data, and develop tentative interpretations about these data through our codes and nascent categories. Then we go back to the field and gather more data to check and refine our categories" (p. 241).

This study used content analysis under the grounded theory method, coding is referred to as the process of breaking down, conceptualizing, and re-assembling data (Strauss & Corbin, 1990). The coding analysis of this study used the grounded theory method with three steps: open coding, categorizing and developing the categories (Appendix G). In this study, open coding was the process of analyzing the data by line, by sentence, and by paragraph (Strauss & Corbin, 1990). Open coding was useful since it helped the researcher to verify and saturate categories that effectively interpreted participants' experiences, and generated the area under study (Holton, 2007). Second, the categorizing step helped the researcher to recognize patterns as similar codes were grouped into categories (Strauss & Corbin, 1990). During categorizing, the researcher identified connections among categories or data. Lastly, in developing the categories step, each category had properties and dimensions (Strauss & Corbin, 1990). Specifically, each category or pattern was considered to have unique characteristics, properties or attributes of a category after categorizing. With this content analyses process, the researcher determined patterns in the study. The results of third research question informed factors of students' MA in LCM and IBL, or reactions to their instructional styles over the course of the semester.

Protection of Human Subjects

Protection of human subjects complied with the standards set by Teachers College, Columbia University's Institutional Review Board. Written permission from the University Director for Research Compliance at the community college was obtained. Subjects were informed by Informed Consent and Participant's Rights documents that their participation was voluntary and results were confidential. Students were asked to sign the consent forms indicating their voluntary participation (Appendix C, D and Appendix E). In order to maintain confidentiality, all surveys and documents were kept in a secure location accessible only by the researcher.

CHAPTER IV

RESULT

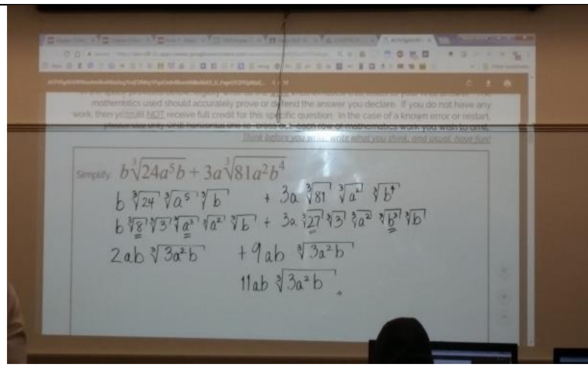
To report the results of this study, which aimed to understand the effect of teachers' different instructional approaches and students' different learning and thinking styles on students' MA, this section is divided into three sections, one descriptive, one quantitative and the other qualitative. In the first section, I briefly describe the five LCM classes and the five IBL classes. The purpose for doing so is to establish that the LCM courses, across instructors, were in fact reasonably similar, and the same for the IBL classes. In the second section, a linear mixed model was applied to see how teachers' two different instructional approaches and students' different learning styles are associated with students' MA. In the third section, students' questionnaires provided insight into students' experiences in their mathematics classrooms, as they related to factors of MA, teacher's teaching styles, the individual's way of learning mathematics, and their attitudes toward learning mathematics. This information has given the researcher sufficient data to understand the study's research questions.

Description of Lecture and Inquiry-Based Learning Classroom

The researcher visited five lecture classrooms and five Inquiry-based learning classrooms one time over 15 academic weeks, writing field notes based on her observation. The field notes were used to reflect on the "analysis, method, and researcher's own frame of mind" (Bogdan & Biklen, 2007, p. 123). The purpose of these notes was to help the researcher ensure that the two different instructional approaches, LCM and IBL, were relatively uniform across all five classes within each model. In order to record field notes while she was in the field, the researcher used an observational protocol described by Creswell (2013). The field notes included the researcher's descriptive and reflective notes. The researcher took about 60 minutes to write down her observations of the 10 different classrooms. By taking both descriptive and reflective notes, the researcher was able to monitor her own thinking of each classroom model, LCM or IBL by asking herself the following question: what are the facts and how does the researcher feel about these facts? Table 11 and Table 12 show the descriptions of the different LCM and IBL classes/instructors.

Table 11. Summary of the Field Notes in IBL

IBL Instructor	**Descriptive notes**	**Reflective notes about teaching**
Prof. TT	"Prof. DD gave clear, precise, and brief lesson by showing several examples of today's objectives at the beginning of the classroom, then focused on students' **group work** for the rest of time… She and her teaching assistant **walked around the classroom** and encouraged students to **engage with their materials** by **working with other students**. Whenever students asked the questions to her how to solve the problem, or whether their answer is correct, she did not answer directly. She kept saying, "What do you think? **Is there another way that you can get the same answer**? **Can you explain how you solved this**?" (field note, 03-12-18)"	- Ask a meaningful question to students instead of giving a direct answer - Through supplemental instruction (SI), students have a small group tutoring with a class learning assistant
Prof. BB	In Prof. BB classroom, there was **a whole-class activity** where students came up to the board to share their answers after they worked in a group. Prof. BB gave different problem sets to every 6 groups, and three or four students spent some time to solve the problems as a group. At the same time, Prof. BB and his teaching assistant **walked around the groups** and asked several questions to **increase students' motivation or interests**" (field note, 03-12-18).	- Used a questioning technique in order to engage all learners - Students became an active learner by discovering, communicating and engaging with their materials and peers -group work
Prof. DW	"When students came to the classroom, they looked at the **"Do Now"** questions on the board. This classroom had a **computer setting environment** (Figure 12), and Prof. WW asked the student to open their google classroom after they finished the "Do Now" question. Prof. WW clicked the keyboard to show the solutions of "Do Now" questions on the screen of the board. He maximized the screen so that all students saw the solutions on the board.	- Computer setting for an individual learner. (Whiteboard, and google classroom is combining with technology) -Technology is a tool as a formative assessment to see students' progress -Students' participation on the board - peer to peer group work

	 Figure 12. Use of technology to share the solutions on the board	-Students understood the routine of using the technology in the classroom
Prof. LL	"Prof. LL had a **differentiation strategy**. Some students solved fast than other students, so she mentioned to the students who finished the given problem earlier move to the next questions. Also, for the students who are under-performed in the same problem, she called volunteer who can **share** his/her solution with other students on the board so that the low-performed students understood how to solve the problem. Also, Prof. LL and TA **walked around** the classroom to check whether the students were doing well, or responded to their questions during the entire classroom. When a student made a mistake in the problem solving, prof. LL just **gave a hint** by explaining the content. Instead of showing all the steps, prof. LL let students solve their problem by themselves" (field note, 03-12-18).	- Through supplemental instruction (SI), students had a small group tutoring with a class learning assistant -Use technology to establish students' mathematical concept such as open educational resources or WeBWork for student's online homework -Discussion and Group work
Prof. JJ	After Prof. RR gave **a short lesson** with the example of linear equation, he made students **in a group**…There were five groups in a classroom, and each group had 3 to 4 students. Prof. RR gave different word problem to each group, and students used a poster to show what and how they were doing in their group work. It seemed that Prof. RR had a strategy such that students **collaborated in a group** to **discover and build** their **conceptual understanding** in a given problem. In a group, students tried to **engage** in finding their own solution by talking, writing, and asking each other. At the same time, Prof. RR **walked around** the classroom giving a hint to the groups. After about 25 minutes, each group came up to the board and shared their poster" (field note, 03-15-18) (figure 13).	-Group work -Demonstration by implementing posters that students collaborated with peers -Discuss ideas, and visualize students' learning. -Presented learning outcomes with the entire class

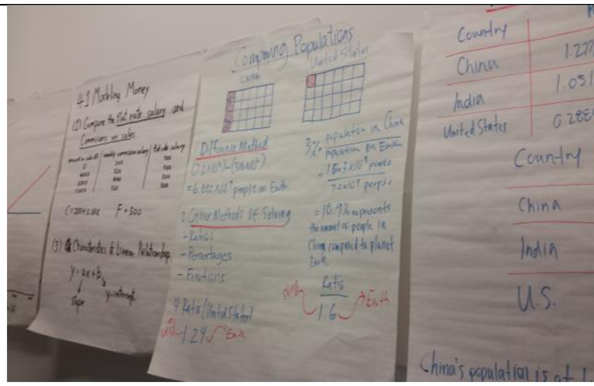


Figure 13. Students' poster presentation in a group work

These observations in IBL confirmed that there were similar teaching strategies among the five IBL instructors, identified four main strategies: 1) active learning including group work and student collaboration, 2) technology integration teaching including WebWork online assignment and open educational resources, 3) supplementary tutoring, and 4) ongoing professional faculty development. In order to support the instructors' beliefs about IBL instructional approaches, they were given the opportunity to participate in a faculty professional development offered by the mathematics department over the 15 academic weeks. They were consistently able to engage with educational technologies, pedagogical strategies, educational practices, problem-based learning, and flipped classroom approaches for students' effective learning in their teaching and learning. Based on this workshop, those teachers' teaching styles and beliefs shaped their instruction, which was enriched by not only their content knowledge but also by their pedagogical knowledge from engaging with other faculty members. The gained pedagogical knowledge facilitated the instructors' ability to use inquiry-based instructional practices and promote positive values about the use of diverse teaching strategies themselves.

Table 12. Summary of the Field Notes in LCM

LCM Instructor	Descriptive notes	Reflective notes about teaching
Prof. DD	"It seemed that there was homework from the last week. Students were expected to finish their homework problems before they came to the classroom. Once they got into the classroom, students submitted their homework on the professor's desk. In 5-10 minutes, Prof. YY began today's lesson which is about a domain. She stated and **wrote the definition of the domain on the board without giving time to students to think about the concept by themselves**…Instead of conveying the conceptual understanding, students just wrote the answers of the domain on their notebook" (field note, 03-09-18).	- Direct presentation with Note taking - Students are passive learner simply listening to the lecture -step-by-step procedures in problem solving -focusing on steps to solve for x -less class activity with peers
Prof. CC	"I found out that Prof. SS went over all the seven questions with the **same routine** during the class: [give problem] – [students spent time] – [Prof. SS walked around to help students] – [went over the problem with step-by-step solution]. After he thought that he gave enough time for students to finish the problem, he asked the students to show their work on the board. Some students came up to the board and wrote their work. **Prof. SS went over by reading students' work on the board**" (field note, 03-12-18).	-go over some problems that students asked - lecture-based classroom - step-by-step procedures
Prof. LO	"I was confused about how all students were engaged with their work since Prof. L **did not walk around** the classroom, and kept **giving a lecture** in the front of the classroom. It was hard to see that students understood the concept or not during the class. One student who wanted to know his work was correct or not so asked to another to check his answer. Other than that, I did not observe the students worked or engaged with each other" (field note, 03-19-18).	- Students look forward during the class -Note taking - Few conversations between an instructor and students -Use only chalks (No use technology)
Prof JO	"Students had a hard time to understand his note on the blackboard!... I was wondering whether all students really understood how to solve the problem. It seemed that students were busy to copy the solution on their note instead of having an enough time to think about the problem that they are solving. Prof. JO showed only one method of the problem, and It seemed that not all students understood his method (field note, 03-12-18)	-Use a blackboard (no technology such as WeBWork or open digital resources) - Note taking - hard to pay attention on the lecture during the entire class session
Prof. SS	"In the problem, $2 = \sqrt[3]{x+4}$, Prof. TT solved for x by writing all **step-by-step work** on the board. He wrote the steps in order to solve the problem on the board: 1) isolate the radial expression, 2) square both sides of the	- Students are passive learner simply listening to the lecture -step-by-step procedures in problem solving

	equation, 3) solve for the unknown. He told students "**remember this step;** then you can solve all types of radical equations" (field note, 03-12-18).	- lecture-based classroom -Emphasize rules and step-by-step procedures

The researcher's observations confirmed that there were similar teaching strategies among the five LCM instructors, primarily characterized by four commonalities: 1) focus on step-by-step skills including formula, memorization, and rules, 2) students as passive learners, 3) less student-to-student activity and fewer group projects, and 4) teacher-centered communication. In general, LCM teachers focused on developing computational skills and teaching rules, and they were more likely to encourage students to develop the same way of problem-solving that they demonstrated in their teaching.

Quantitative Data Analysis

In the beginning of the semester, 246 students participated in the pre-survey to measure their MA level and learning and thinking styles. During the 15 academic weeks, 29 students in IBL dropped the classes and 32 students in LCM dropped the classes. By the end of the semester, 185 students participated in the post-survey to measure their MA levels. 88 of them were in a lecture classroom model (LCM), and the remaining 97 were in an inquiry-based classroom model (IBL). In order to analyze the collected data, the following fifteen variables were structured (Table 13). The data file contains data collected by the researcher.

Table 13. Data code and description

	Data Code	Description
1	IBL	0 = an indicator that students belonged to lecture classroom model 1= an indicator that students belonged to Inquiry-based learning classroom model
2	Kolb's Learning Styles	An indicator that students belonged to Diverger, Assimilator, Converger, Accommodator, or K-flexible
3	Gregorc's Thinking Styles	An indicator that students belonged to Concrete Sequential, Concrete Random, Abstract Sequential, Abstract Random, or G-flexible
4	Pre-/Post-AMARS	Mathematics anxiety levels in pre and post survey over the 15 weeks of the semester (A-MARS item 1 to 25).
5	Pre-/Post-TA	Test anxiety levels in pre and post survey over the 15 weeks of the semester (A-MARS item 1 to 15).
6	Pre-/Post-NA	Numeric anxiety levels in pre and post survey over the 15 weeks of the semester (A-MARS item 16 to 20).
7	Pre-/Post-MCA	Mathematics course anxiety levels in pre and post survey over the 15 weeks of the semester (A-MARS item 21 to 25).

Note. K-Flexible and G-Flexible are indicators reflecting students who belonged to more than two learning styles in each Kolb's and Gregorc's learning styles model.

An assumption of the Regression Model.

One of the multiple linear regression models (Pre-AMARS = b 0 + b 1 * (Pre-AMARS) + b 2 * (IBL) is presented here as a representation of testing the effect of the independent variables (Pre-MA levels and IBL) on the dependent variables (Post-MA levels). First, the researcher tested multicollinearity to determine whether the predictor variables (Pre-MA levels and IBL) are linearly predicted from the others with a substantial degree of accuracy. The Variance Inflation Factor (VIF) values (VIF = 1.001) was close to 1, which implies that there was no multicollinearity between the predictor variables (Pre-MA levels and IBL) (Appendix H). Second, normality of the residuals was tested and there was evidence of non-normality due to one extreme outlier on the positive side (Figure 14). Removing this participant removed the non-normality from the distribution of the residuals, but did not change the pattern of result for the regression model (Figure 15), which means that there are no sizeable issues in the data.

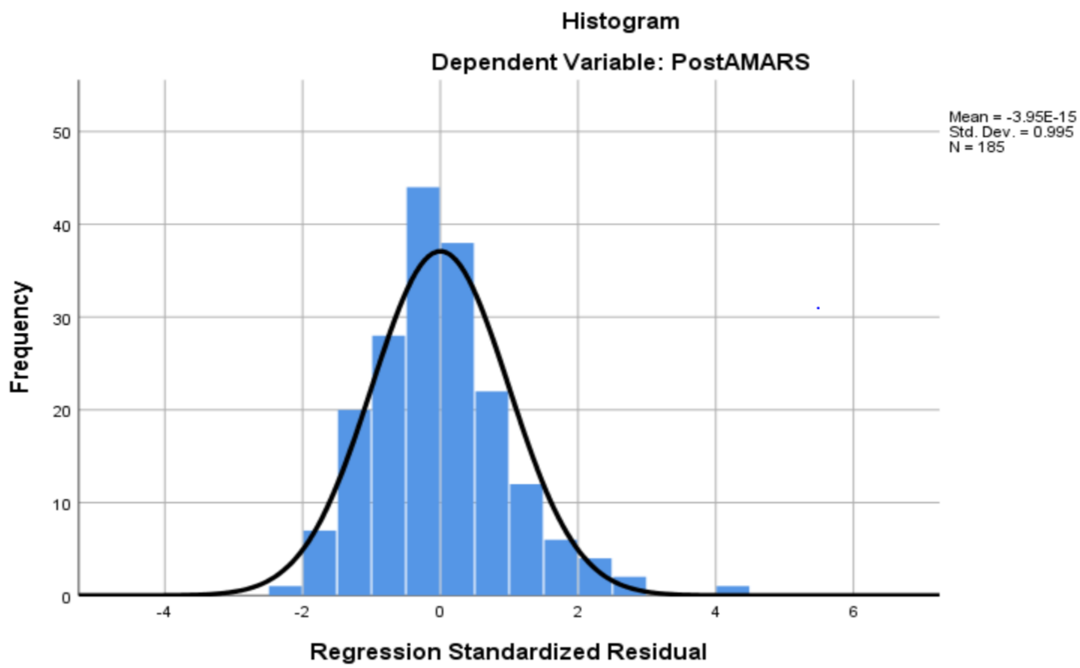


Figure 14. Non-normality distribution before removing the outlier

Note. There was one participant as an outliner, which provides the regression model is a non-normality

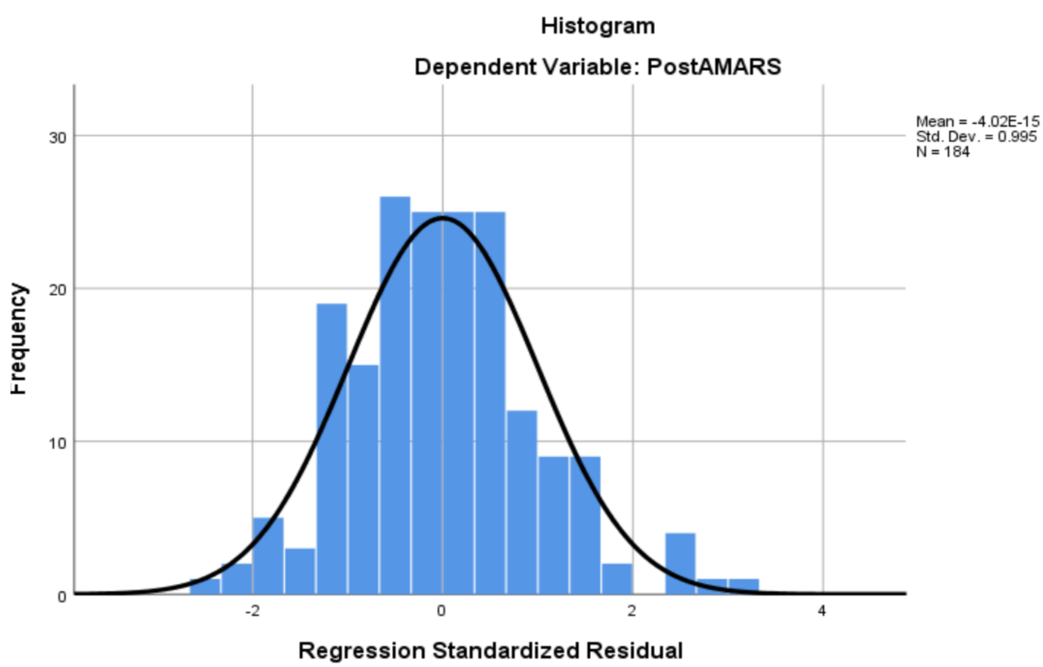


Figure 15. Normality distribution after removing the outlier

Note. The residuals are normally distributed removing the outliner.

Abbreviated Mathematics Anxiety Levels (A-MARS) in LCM and IBL of MAT 56

The researcher broke down the A-MARS scores into three categories: little to no anxiety, medium feelings of anxiety, and intense feelings of anxiety. (This is consistent with what others (e.g., Faith, 2016) have done.) The researcher divided the range of A-MARS scores into three equal parts by taking the range of the A-MARS's lowest possible score of 1 and the highest possible score of 5. For example, if the students' A-MARS scores ranged from 1.00 to 2.32, they were considered to have little to no MA: if the students' A-MARS scores ranged from 2.33 to 3.65, they were identified having medium feelings of MA: if the students' A-MARS scores ranged from 3.66 to 5.00, they were estimated to have strong feelings of MA (Faith, 2016).

Table 14 demonstrates that, for IBL classes, the percentage of students who had little to no MA increased from approximately 39% to 49%, those who had medium feelings of MA decreased from 49.5% to 43.4%, and those who had strong feeling of MA decreased from 11.3% to 8.2% over the 15 academic weeks. For LCM classes, the percentage of the students who had little to no MA decreased from approximately 35% to 34%, those who had medium feelings of MA decreased from 51.5% to 45.5%, and those who had strong feelings of MA increased from 13.6% to 20.5% over the 15 academic weeks. The percent change of the students who had a strong feelings of MA in LCM increased by 6.9% whereas the percent change of the students who had strong feelings of MA in IBL decreased by 3.1%. These results provide an initial picture as to how students' MA levels changed in LCM and IBL classes throughout the semester.

Table 14. A-MARS Scales in pre-and post-survey in lecture classes and inquiry-based learning classes.

Period	**Pre-survey in IBL**		**Post-survey in IBL**		
Range A-MARS	Number of students	Percentage	Number of students	Percentage	Percent Change
No MA (1.00 to 2.32)	38	39.2%	47	48.5%	9.3%
Medium of MA (2.33 to 3.65)	48	49.5%	42	43.3%	-6.2%
Strong of MA (3.66 to 5.00)	11	11.3%	8	8.2%	-3.1%
Total	97	100%	97	100%	

Period	**Pre-survey in LCM**		**Post-survey in LCM**		
Range A-MARS	Number of students	Percentage	Number of students	Percentage	Percent Change
No MA (1.00 to 2.32)	31	35.2%	30	34.1%	-1.1%
Medium of MA (2.33 to 3.65)	45	51.1%	40	45.5%	-5.6%
Strong of MA (3.66 to 5.00)	12	13.6%	18	20.5%	6.9%
Total	88	100%	88	100%	

Research Question 1

The first research question in this study was a comparison of the level of MA between two different instructional styles: Lecture classroom model (LCM) and Inquiry-based learning classroom model (IBL), among college students who were taking MAT 56 at an urban community college. The research question was: What is the difference between a lecture classroom model (LCM) and an inquiry-based learning classroom model (IBL) on students' MA levels over a fifteen-week semester of a college-level remedial mathematics course? This question is intended to determine whether different teaching instruction explains some of the students' MA level changes over one semester.

The researcher accounted for the correlation between the student measurement within an instructor, and thus to minimize the error term, used a linear mixed model. For example, each of the 10 different classes has their own intercepts by its different instructor, meaning that there is a different average of MA levels in each class. It implies that students' MA levels from the same instructor cannot be regarded as independent from each other. This would be an idiosyncratic factor affecting all responses from the same LCM or IBL instructor, and thus the researcher accounted for the correlation of students nested within instructors running the linear mixed model. The linear mixed model was conducted to estimate different instructors' intercepts using random effect for instructors. Thus, the researcher was able to assume that students' MA levels within LCM or IBL classrooms were similar due to instructors and /or their similar instructional approaches with the following linear mixed model: post-MA levels (e.g. post-TA, post-NA and post-MCA) = $b_0 + b_1$*pre-MA levels (pre-TA, pre-MA, and pre-MCA) +b_2*(IBL) + b_i*(1 | instructor) + e. In this series of equations, i refers to the different instructors.

The two hypotheses for research question 1 were

1. H_0: There is no difference between pre and post-mathematics anxiety (TA, NA, and MCA) levels over the 15 academic weeks in LCM and IBL
2. H_a: There is difference between pre and post-mathematics anxiety (TA, NA, and MCA) levels over the 15 academic weeks in LCM and IBL

In the regression analysis, post-AMARS = $b_0 + b_1$ *(pre-AMARS) + b_2 *(IBL) + e, there was a significant difference (F = 61.921, p-value =0.000) in students' overall mathematics anxiety (AMARS) level between LCM and IBL classes. Before running the linear mixed model, the intraclass correlation coefficient (ICC) was calculated because the collected individual data was made on units that were organized into classes. The calculated ICC describes how strongly units in the same classes resembled each other. An ICC value greater than 0.05 indicates that there existed a similarity between values from the same group. In this study, 185 students were organized into 10 different classes, and a high degree of reliability (ICC = 0.05) (Appendix I) was found between AMARS measurements which implies that there was a similarity among five

LCM classes and among the other five IBL classes. In “Estimates of Fixed Effects” (Table 15), a linear mixed model of post-AMARS = $b_0 + b_1$*pre-MA + b_2*IBL+ b_i* (1 | instructor) + e was conducted, and it gives the p-value which approached the borderline of being significant (p-value = 0.07) in terms of students' overall mathematics anxiety (AMARS) level between LCM and IBL classes. Once accounting for the repeated-measure correlation within group, the fixed effects were reduced from significant to insignificance. The table 15 shows that the AMARS was reduced by 0.2959, on average, when students had classes with IBL over the 15 academic weeks compared to the other LCM classes. The researcher found that students typically reduced their AMARS levels when they took the course in IBL at the margin of statistical significance. Learning mathematics with IBL instructors tended to reduce students’ AMARS levels over the 15 academic weeks.

Table 15. Estimates of Fixed Effects for the AMARS of RQ 1

	Estimate	St. Error	DF	t-stat	p-value
Intercept	1.1694	0.1890	174	6.1856	0.000
Pre-AMARS	0.6267	0.0593	174	10.557	**0.000**
IBL	-0.2959	0.1447	8	-2.0438	**0.0752**

Note. A mixed model analysis with post-AMARS = $b_0 + b_1$*pre-MA + b_2*IBL + b_i* (1 | instructor) + e

From the previous literature review, the Abbreviate Mathematics Anxiety Scale (A-MARS) has 25-items, with three sub-scales: Mathematics Test Anxiety (items 1-15); Numerical Task Anxiety (items 16-20); and Mathematics Course Anxiety (items 21-25) (Alexander & Martray, 1989). A regression model was used to determine whether there were any statistically significant differences among three different MA levels, mathematics test anxiety (TA), numerical task anxiety (NA), and mathematics course anxiety (MCA) in LCM and IBL. Only the results of TA and MCA show that there was a significant difference between teaching styles.

In the regression analysis for TA, post-TA= $b_0 + b_1$ *(pre-TA) + b_2 *(IBL) + e, there was a significant difference (F = 77.020, p-value =0.000) in students' overall test anxiety (TA) level between LCM and IBL classes. The ICC (= 0.02) shows a low degree of reliability between TA measurements which implies that there was no similarity among five LCM classes and five IBL classes (Appendix I). In "Estimates of Fixed Effects" (Table 16), a linear mixed model of post-TA = $b_0 + b_1$*pre-TA + b_2*IBL + (1 | instructor) + e was conducted, and it showed a significant difference between LCM and IBL (p-value = 0.021). Table 16 shows that the TA levels dropped by 0.3801, on average, when students had classes with IBL over the 15 academic weeks. The researcher found that students typically reduced their TA levels when they took the course in IBL with a strong statistical significance. Learning mathematics with IBL instructors was associated with reduced students' TA levels over the 15 academic weeks.

Table 16. Estimates of Fixed Effects for the TA of RQ 1

	Estimate	St. Error	DF	t-stat	p-value
Intercept	1.2818	0.1916	174	6.6898	0.000
Pre-TA	0.6575	0.0553	174	11.8711	**0.000**
IBL	-0.3801	0.1327	8	-2.8634	**0.021**

Note. A mixed model analysis with post-TA = $b_0 + b_1$*pre-TA + b_2*IBL + b_i* (1 | instructor) + e

In the regression analysis for NA, post-NA= $b_0 + b_1$ *(pre-NA) + b_2 *(IBL) + e, there was a no significant difference (F = 33.873, p-value =0.601) in students' overall NA level between LCM and IBL classes. The ICC (= 0.04) shows (Appendix I) a low degree of reliability between TA measurements which implies that there was no similarity among five LCM classes and other five IBL classes. In "Estimates of Fixed Effects" (Table 17), a linear mixed model of post-NA = $b_0 + b_1$*pre-NA + b_2*IBL + (1 | instructor) + e was conducted, and it showed insignificant difference between LCM and IBL (p-value = 0.742); the researcher did not find statistically significant difference in NA levels when students took the course in IBL over the 15 academic weeks; Learning mathematics with IBL instructors was not associated with reduced students' NA levels over the 15 academic weeks.

Table 17. Estimates of Fixed Effects for the NA of RQ 1

	Estimate	St. Error	DF	t-stat	p-value
Intercept	0.8220	0.1956	174	4.2016	0.000
Pre-NA	0.5656	0.0699	174	8.0826	**0.000**
IBL	-0.0610	0.1790	8	-0.3407	**0.742**

Note. A mixed model analysis with post-NA = $b_0 + b_1$*pre-NA + b_2*IBL + b_i* (1 | instructor) + e

Lastly, in the regression analysis, post-MCA= $b_0 + b_1$ *(pre-MCA) + b_2 *(IBL) + e, there was a significant difference (F = 58.807, p-value =0.000) in students' mathematics course anxiety (MCA) level between LCM and IBL classes. A high degree of reliability (ICC = 0.05) (Appendix I) was found between MCA measurements which implies that there was a similarity among five LCM classes and other five IBL classes. In “Estimates of Fixed Effects” (Table 18), a linear mixed model of post-MCA = $b_0 + b_1$*pre-MCA + b_2*IBL + (1 | instructor) + e was conducted, and it gives the p-value which approached the borderline of significance (p-value = 0.07) in students' overall math course anxiety (MCA) level between LCM and IBL classes. Table 18 shows that MCA levels dropped by 0.3714, on average, when students had classes with IBL over the 15 academic weeks. The researcher found that students typically reduced their MCA levels when they took the course in IBL with a statistical significance (p-value = 0.07). Learning mathematics with IBL instructors was associated with reduced students’ MCA levels over the 15 academic weeks.

Table 18. Estimates of Fixed Effects for the MCA of RQ 1

	Estimate	St. Error	DF	t-stat	p-value
Intercept	1.0856	0.1834	174	5.9192	0.000
Pre-MCA	0.6026	0.0594	174	10.132	**0.000**
IBL	-0.3714	0.1788	8	-2.0765	**0.0715**

Note. A mixed model analysis with post-MCA = $b_0 + b_1$*pre-MCA + b_2*IBL + b_i* (1 | instructor) + e

The researcher compared the MA levels in each LCM and IBL of the four different MA levels (AMARS, TA, NA, and MCA). In Figure 16, a horizontal x-axis labels "Time," indicating that the time changes from pre-survey to post-survey, and the MA levels (TA, NA, and MCA) were placed along the vertical y-axis. When the average of MA in each pre- and post-survey were plotted to make the relevant trends more visually in the graph, the timeline of MA levels (TA, NA, and MCA) shows that there was a difference in LCM and IBL over the 15 academic weeks; only AMARS, NA, and MCA shows that there was a significant difference between LCM and IBL. TA can be comparable between LCM and IBL. In overall, the students in LCM increased their MA levels, and the students in IBL reduced their MA over the same period.

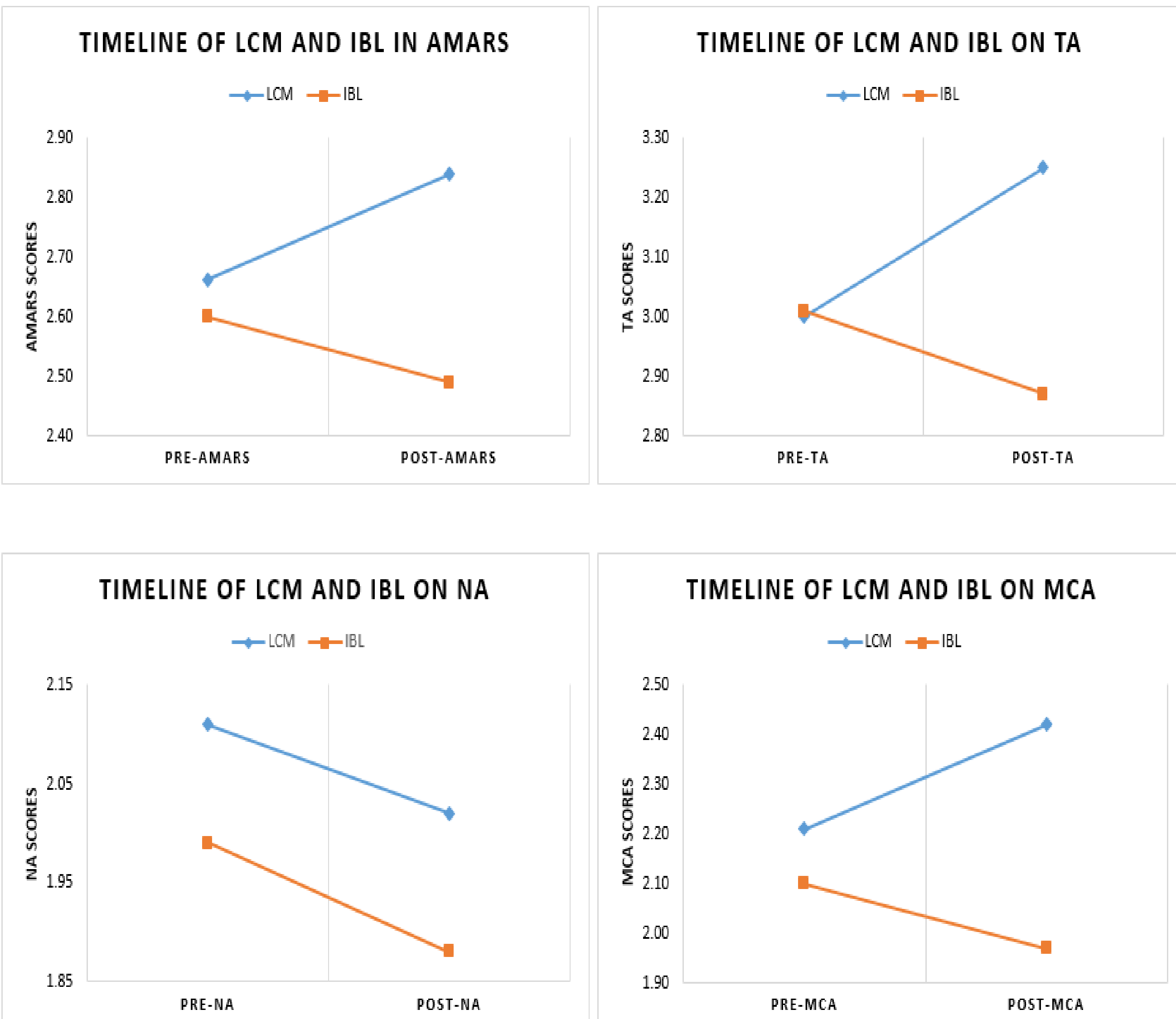


Figure 16. A timeline of MA changes (AMARS, TA, NA, and MCA) in LCM and IBL over the 15 academic weeks.

To summarize the findings from research question 1, the regression analyses results show that changes in overall mathematics anxiety (AMARS), test anxiety (TA), and mathematics course anxiety (MCA) were different between LCM and IBL instructional styles over the 15 academic weeks: IBL models being associated with decreased MA levels.

Research Question 2 with Kolb's Learning Style

Claim for K- flexible learning styles. The participants' learning styles (identified by Kolb, 1984) were defined during the pre-survey period. After analyzing the participants' learning styles, the researcher identified some participants as having different combinations of learning preferences, which is not defined in Kolb's learning styles. For example, in Kolb's model, the combination of concrete experience (CE) and abstract conceptualization (AC), or the combination of abstract experiment (AE) and reflective observation (RO) did not belong to Kolb's original learning styles, since Kolb believed that learners could not "think" and "feel" at the same time. However, there were a number of participants (n = 19) who had a combination of CE and AC or a combination of AE and RO in the current study, which is not defined by Kolb. Therefore, the researcher created another learning style, called Kolb-Flexible (K-Flexible) to describe the participants who had a combination of CE and AC or AE and RO as their learning styles (Table 19).

Table 19. K-flexible learning styles in Kolb's model

Learning Style created by a researcher	Combination of
K-flexible	CE and AC
	AE and RO
Total Number	19

Note. The combination of concrete experience (CE) and abstract conceptualization (AC), or abstract experiment (AE) and reflective observation (RO) were combined as a new learning style for the study, called K-Flexible.

Participants in Kolb's learning styles. Out of 185 participants who completed both pre and post survey the 15 academic weeks, there were 51 students with diverger learning styles, 31 with assimilator learning styles, 38 with converger learning styles, 45 with accommodator learning styles, and 19 with K-flexible learning styles (Table 20). In LCM, there were 19 students with diverger learning styles, 11 with assimilator learning styles, 22 with converger learning styles, 25 with accommodator, and 11 with K-flexible learning styles. In IBL, there were 31 students with diverger learning styles, 20 with assimilator learning styles, 20 with converger learning styles, 18 with accommodator, and 8 with K-flexible learning styles (Table 21).

Table 20. Descriptive statistics table of learning styles

Descriptive Statistics	
Kolb's learning styles	N
Diverger	51
Assimilator	32
Converger	38
Accommodator	45
K-Flexible	19
Total	185

Note. K-Flexible is a learning style that is created by the researcher in Kolb's model.

Table 21. Descriptive statistics table of learning styles in each LCM and IBL.

	Kolb's learning styles	**N**		**Kolb's learning styles**	**N**
LCM	Diverger	19	**IBL**	Diverger	31
	Assimilator	11		Assimilator	20
	Converger	22		Converger	20
	Accommodator	25		Accommodator	18
	K-Flexible	11		K-Flexible	8
	Total	88		Total	97

Before the researcher ran the linear mixed model for the second research question with Kolb's learning styles, the researcher first tested the interaction effects between teaching styles and Kolb's learning styles to predict post-MA levels based on pre-MA, IBL and Kolb' learning styles. In the model, post-MA (AMARS, TA, NA, and MCA) = $b_0 + b_1$ *pre-MA (AMARS, TA, NA and MCA) + b_2 * (IBL) + b_3*(Kolb's learning styles) + b_4* (IBL) (Kolb's learning styles) + e, the interaction effects were not significant. Then, the researcher ran the model to respond to the second research question by removing the interaction effects between IBL and Kolb's learning styles to test the main effects.

Moreover, before the researcher ran the regression, the following graphs show the relationship between MA levels (AMARS, TA, NA, and MCA) and each learning style (defined by Kolb's) in each LCM and IBL over the 15 academic weeks. In Figure 17, the horizontal x-axis is labeled "Time," indicating that the time changes from pre-survey to post-survey in LCM, and the MA levels (AMARS, TA, NA, and MCA) are placed along the vertical y-axis for each learning style. For example, when the averages of MCA of Kolb's learning styles in each pre- and post-survey were plotted, the timeline of the MCA shows that all learning styles correlated with a reduction of students' MCA in LCM over the 15 academic weeks. In Figure 18, the horizontal x-axis is labeled "Time," indicating that the time changes from pre-survey to post-survey of IBL, and the MA levels (AMARS, TA, NA, and MCA) are placed along the vertical y-axis for each learning styles. For example, when the averages of MCA of Kolb's learning styles in each pre- and post-survey were plotted, the timeline of the MCA shows that all learning styles correlated with a reduction of students' MCA in IBL over the 15 academic weeks.

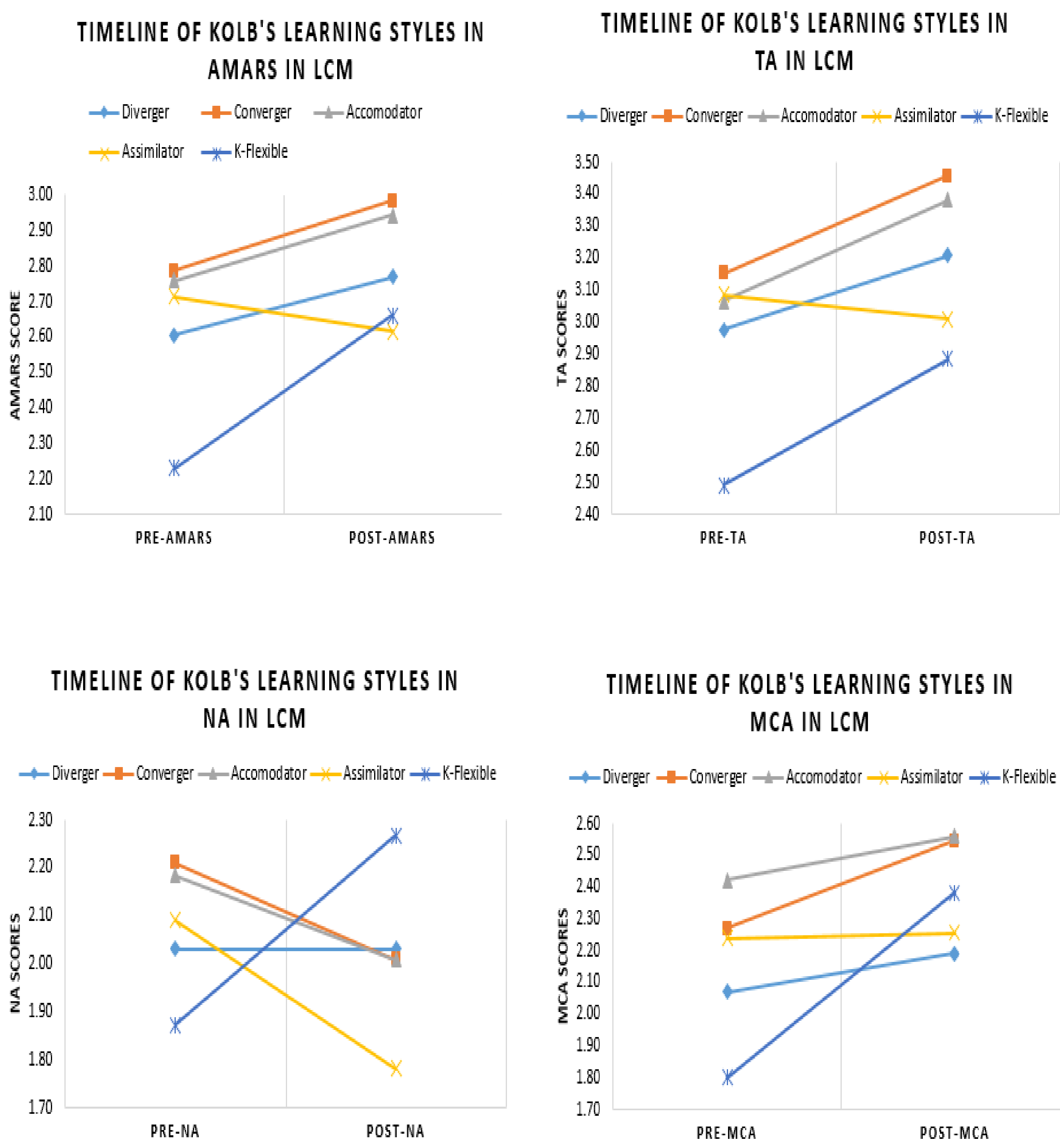


Figure 17. A timeline of MA changes (AMARS, TA, NA, and MCA) in LCM for the students with different learning styles (defined by Kolb's) over the 15 academic weeks.

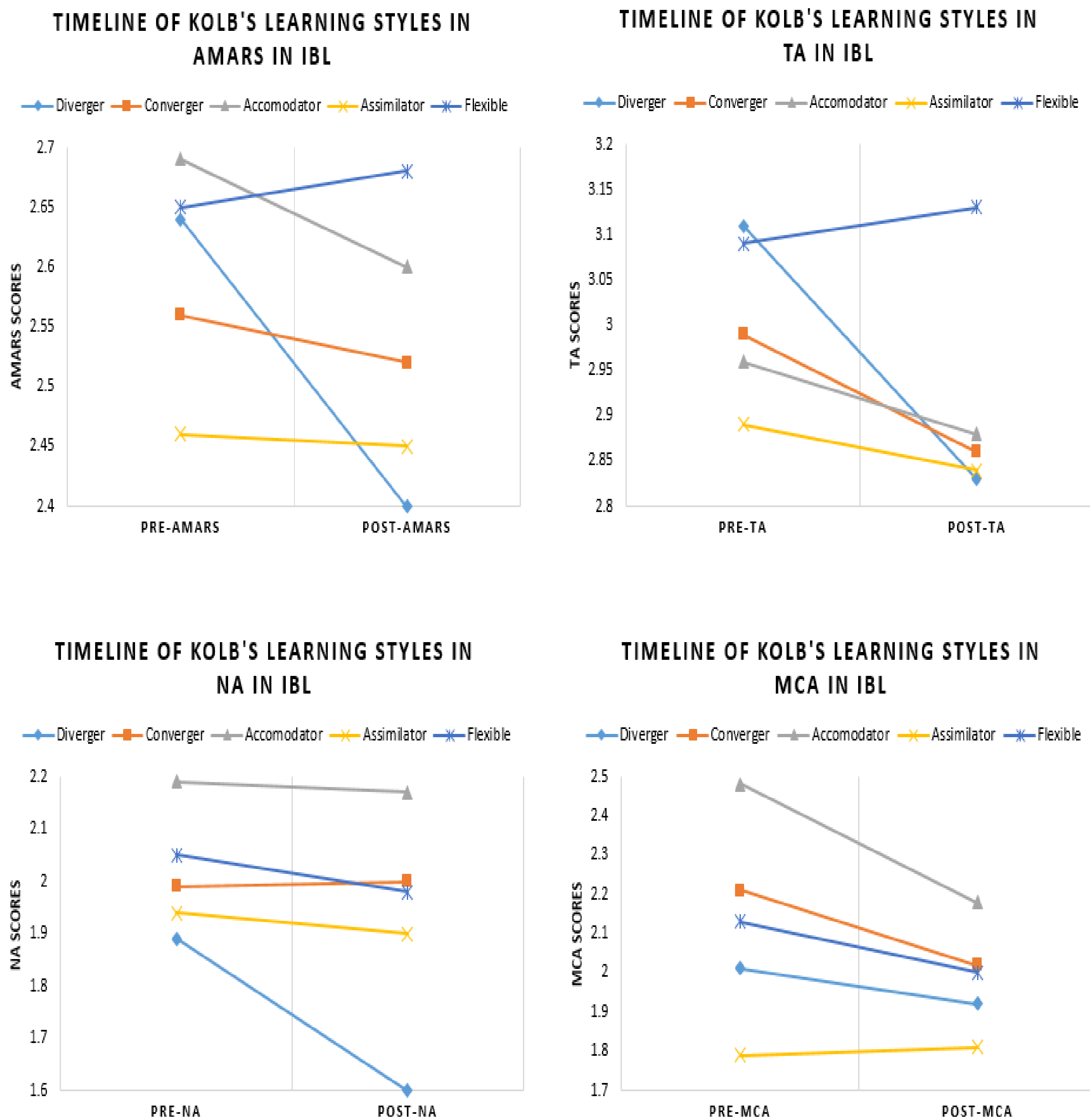


Figure 18. A timeline of MA changes (AMARS, TA, NA, and MCA) in IBL for the students with different learning styles (defined by Kolb's) over the 15 academic weeks.

Research Question 2 analyses with Kolb's learning styles. The second research question investigated the association between MA and two different teaching styles, LCM and IBL, for students with different learning styles: What is the difference between an LCM classroom and an

IBL classroom on MA levels for students with different learning styles (as defined by Kolb's learning styles) over a fifteen-week semester? A linear mixed model was used with the following model: post MA levels (e.g., post-TA, post-MA and post-MCA) = b_0 + b_1 * pre-MA levels (e.g. pre-TA, pre-MA, and pre-MCA) + b_2 * (IBL) + b_3 * (Kolb's Learning Styles) + b_i * (1 | Instructor) + e. There are two hypotheses for research question 2 with Kolb's learning styles:

1. H_0: The influence of teaching styles on mathematics anxiety levels (TA, NA and MCA) over the 15 academic weeks will be the same for students with different learning styles defined by Kolb.
2. H_a: The influence of teaching styles on mathematics anxiety levels (TA, NA and MCA) over the 15 academic weeks will not be the same for students with different learning styles defined by Kolb.

A multiple linear regression was calculated to predict post-AMARS based on pre-AMARS, IBL and Kolb' learning styles, post-AMARS= b_0 + b_1 * (pre-AMARS) + b_2 * (IBL) + b_3 * (Kolb's learning styles) + e. In this model, pre-AMARS levels was coded as a numerical value, IBL was coded as 0 = LCM and 1 = IBL, and Kolb's learning styles was coded as a categorical data (diverger, assimilator converger, accommodator and K-flexible). A significant regression equation was found (F = 20.787, p = 0.0123), with an R^2 of 0.412. Both pre-AMARS and IBL were significant predictor of post-AMARS; however, diverger, assimilator, converger, and accommodator were not significant predictors of post-AMARS. Before running the linear mixed model, the researcher found the ICC (= 0.05) (Appendix J) between AMARS measurements inferring that there was a similarity among five LCM classes and the other five IBL classes. In "Estimates of Fixed Effects" (Table 22), a linear mixed model gives the significant p-value (<0.000) in only pre-AMARS. After accounting for the repeated-measure correlation within group, the fixed effects were reduced from significant to non-significance of IBL. Therefore, there was no evidence to reject the null hypothesis in students' AMARS between LCM and IBL for students in different learning styles defined by Kolb over the 15-academic weeks; the MA levels of the students who learned math under the IBL instruction was reduced. However, based on Kolb's learning styles construct, students' learning styles was not associated with reduced MA levels above and beyond the instructional distinction (IBL or LCM) over the 15 academic weeks.

Table 22. Estimates of Fixed Effects for the AMARS with Kolb's learning styles

Variable	Coefficient	Standard. Error	t-value	Pr > |t|
Intercept	1.2648	0.2350	5.3818	<.0000
Pre-AMARS	0.6263	0.0600	10.4376	**<.0000**
IBL	-0.2654	0.1484	-1.7883	0.1115
Diverger	-0.2119	0.1937	-0.0939	0.2755
Assimilator	-0.1707	0.2105	-0.8110	0.4185
Converger	-0.0526	0.1989	-0.2647	0.7915
Accommodator	-0.0512	0.1994	-0.2569	0.7975

Note. There is no significant difference in AMARS among students with different learning styles except Pre-AMARS in a linear mixed model.

The same tests were run with the linear mixed model for each of the subscales of AMARS (TA, NA, and MCA), with similar results. There was no sufficient evidence to reject null hypothesis in students' TA, NA, and MCA for students with different learning styles defined by Kolb over the 15-academic weeks. (Appendix K). To summarize, the results for research question 2 with Kolb' learning styles (n = 185) show that only pre-MA levels appear to be a significant factor in reducing post-MA levels every time; the results of research question 2 with Kolb's learning styles suggest that teaching styles may help alleviate anxiety, but the entire construct of students' learning styles appears to be less related to MA.

The researcher further explored research question 2 by looking at specific learning styles within Kolb's model. For example, given the students with diverger learning styles (n = 51), the post AMARS scores decreased by, on average, 0.3932 points (p-value = 0.0495) when they took classes with IBL instead of LCM over the 15 academic weeks; diverger student's post-TA also decreased by 0.4617 (p-value = 0.0441). Also, given the students with converger learning styles (n =42), the post-TA decreased by 0.5789 (p-value = 0.00061) (Appendix L). These results are also evident in Figures 17 and 18 above. Specifically, in IBL, the AMARS and TA levels of diverger learners were sharply decreased (Figure 18) compared to AMARS and TA levels of diverger learners in LCM over the same academic period (Figure 17). The analysis with selected samples of learning styles demonstrates that diverger and converger learners in IBL tended to reduce their MA levels more so than in LCM classes by learning through student-centered learning approaches. These findings may be further investigated in future studies about whether there are qualities about these particular learning styles (diverger and converger) that tend to reduce students' MA levels in a student-centered learning environment.

Research Question 2 with Gregorc's Thinking Styles

Claim for G-flexible thinking style. In determining participants' thinking styles (identified by Gregorc, 1984), some participants had two or three highest identical scores when adding the total for each column I, II, III, and IV as their learning style (Appendix E). There were a number of participants (n=33) who had two or three equal scores among the four learning styles, concrete sequential (CS), abstract sequential (AS), abstract random (AR) and concrete random (CR). Gregorc did not identify these combinations and the researcher created another thinking style, called Gregorc-Flexible (G-Flexible), which implies that participants have more than two thinking styles (Table 23).

Table 23. G-flexible thinking styles in Gregorc's model.

Thinking Styles created by a researcher	Same Highest Scores	Combination of
G-Flexible	Two highest equal scores	Among CS, AS, AR, and CR
Total Number		30
G-Flexible	Three highest equal scores	Among CS, AS, AR, and CR
Total Number		3

Participants in Gregorc's thinking styles. Out of the 185 participants who remained and completed both pre and post survey over the 15 academic weeks, there were 44 students with concrete sequential (CS) learning styles, 28 with concrete random (CR) learning styles, 24 with abstract sequential (AS) learning styles, 56 with abstract random (AR) learning styles, and 33 with G-flexible learning styles (Table 24). In LCM, there were 20 with CS learners, 13 with CR learners, 10 with AS learners, 28 with AR learners, 17 with G-flexible learners. In IBL, there were also 24 with CS learners, 15 with CR learners, 14 with AS learners, 28 with AR learners, and 16 with G-flexible learners (Tables 25).

Table 24. Descriptive statistics table of Gregorc's thinking styles.

Descriptive Statistics	
Gregorc's thinking styles	N
CS	44
CR	28
AS	24
AR	56
G-Flexible	33
Total	185

Note. G-Flexible is a thinking style that is created by the researcher in Gregorc's model

Table 25. Descriptive statistics table of Gregorc's thinking styles in LCM and IBL.

	Gregorc's thinking styles	**N**		**Gregorc's thinking styles**	**N**
LCM	CS	20	**IBL**	CS	24
	CR	13		CR	15
	AS	10		AS	14
	AR	28		AR	28
	G-Flexible	17		G-Flexible	16
	Total	88		Total	97

Before the researcher ran the linear mixed model for the second research question with Gregorc's thinking styles, the researcher first tested the interaction effects between teaching styles and Gregorc's thinking styles to predict post-MA levels based on pre-MA, IBL and Kolb' learning styles. In the model, post-MA (AMARS, TA, NA, and MCA) = $b_0 + b_1$ *pre-MA

(AMARS, TA, NA and MCA) + b_2 * (IBL) + b_3 * (Gregorc's thinking styles) + b_4* (IBL) (Gregorc's thinking styles) + e, the interaction was not significant. Then, the researcher ran the model to respond to the second research question by removing the interaction effects between IBL and Gregorc's thinking styles to test the main effects.

Moreover, before the researcher ran the regression, the following graphs show the MA levels (AMARS, TA, NA, and MCA) of students' different thinking styles (defined by Gregorc) in each LCM and IBL instruction classes over the 15 academic weeks. In Figure 19, a horizontal x-axis is labelled "Time," indicating that the time changes from pre-survey to post-survey in LCM, and the MA levels (AMARS, TA, NA, and MCA) are placed along the vertical y-axis for each thinking style (Figure 19). For example, when the average MA (AMARS, TA, NA, and MCA) of Gregorc's thinking styles in each pre- and post-survey were plotted, the timeline of the all MA levels shows that all thinking styles tended to correlate with an increase in students' MA levels (AMARS, TA, NA, and MCA) in LCM over the 15 academic weeks. In Figure 20, a horizontal x-axis is labelled "Time," indicating that the time changes from pre-survey to post-survey of IBL, and the MA levels (AMARS, TA, NA, and MCA) are placed along the vertical y-axis for each thinking styles. For example, when the average MA (AMARS, TA, NA, and MCA) of Gregorc's thinking styles in each pre- and post-survey were plotted, the timeline of the MA levels (AMARS, TA, NA, and MCA) shows that all thinking styles tended to correlate with a reduction in students' MA levels (AMARS, TA, NA, and MCA) in IBL over the 15 academic weeks.

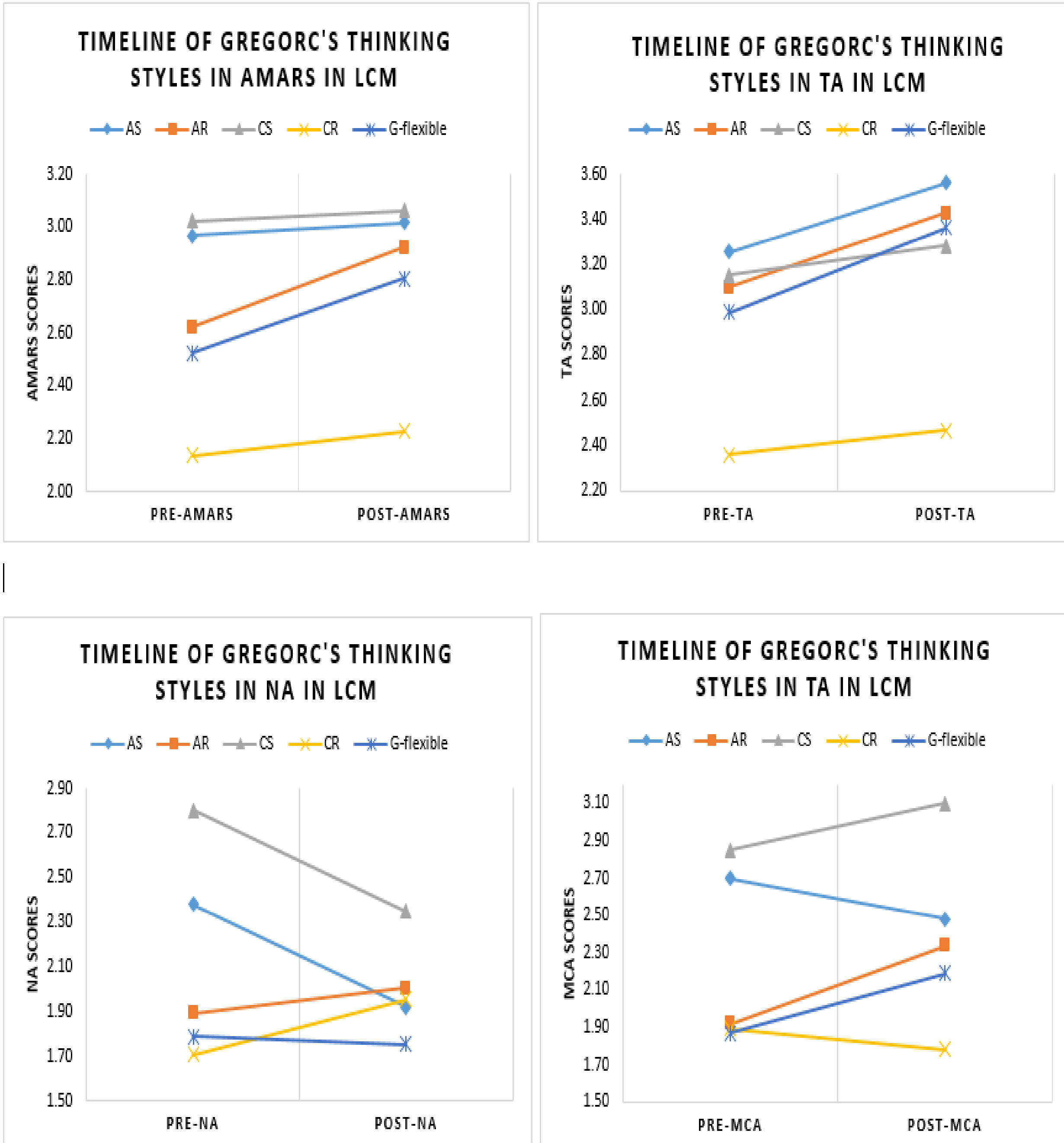


Figure 19. A timeline of MA changes (AMARS, TA, NA, and MCA) in LCM for the students with different thinking styles (defined by Gregorc's) over the 15 academic weeks.

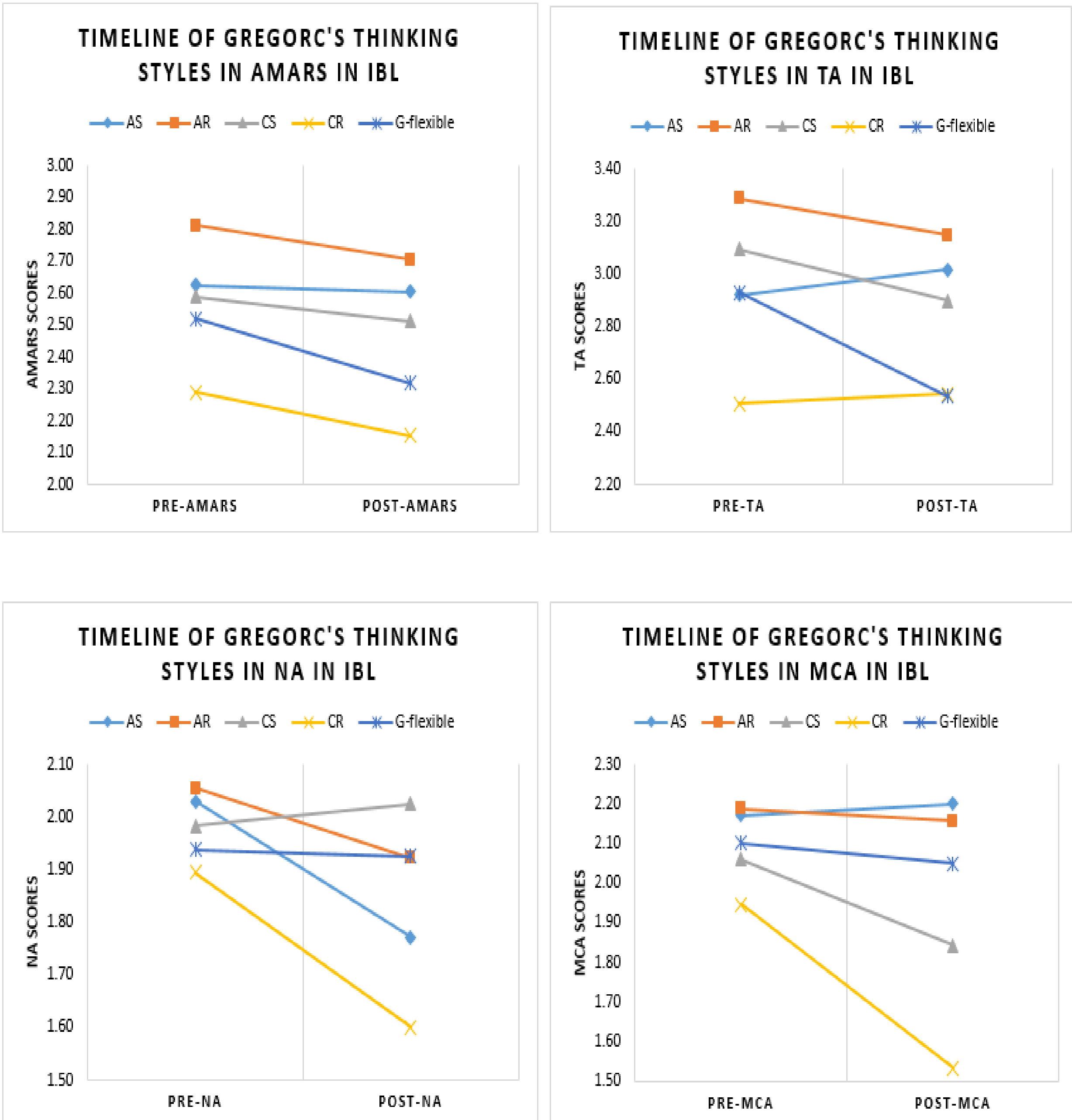


Figure 20. A timeline of MA changes (AMARS, TA, NA, and MCA) in IBL for the students with different thinking styles (defined by Gregorc's) over the 15 academic weeks.

Research question 2 analyses with Gregorc's thinking styles. The second research question investigated the association between MA and two different teaching styles, LCM and IBL, for students with Gregorc's different thinking styles; What is the difference between LCM and IBL instruction on MA levels for students with different thinking styles (as defined by

Gregorc's thinking styles) over a fifteen-week semester? A linear mixed model was used with the following model: post MA levels (e.g. post-TA, post-MA and post-MCA) = b_0+ b_1 * pre MA levels (e.g. pre-TA, pre-MA, and pre-MCA) + b_2 *(IBL) + b_3 * (Gregorc's thinking styles) + b_i *(1 | instructor) + e. There are two hypotheses for the research question 2 with Gregorc's thinking styles:

1. H_0: The influence of teaching styles on mathematics anxiety levels (TA, NA, MCA) over the 15 academic weeks will be the same for students with different thinking styles defined by Gregorc.
2. H_a: The influence of teaching styles on mathematics anxiety levels (TA, NA, MCA) over the 15 academic weeks will not be the same for students with different thinking styles defined by Gregorc.

A multiple linear regression was used to predict post-AMARS based on pre-AMARS, IBL and Gregorc' thinking styles, post-AMARS= b_0 + b_1 * (pre-AMARS) + b_2 * (IBL) + b_3 * (Gregorc's thinking styles) + e. Similar to Kolb's model, pre-AMARS level was coded as a numerical value, IBL was coded as 0 = LCM and 1 = IBL, and Gregorc's thinking styles were coded as a categorical data (AR, AS, CR, CS, and G-flexible). A significant regression equation was found ($F = 21.153$, $p <0.000$), with an R^2 of 0.416. Both pre-AMARS and IBL were significant predictors of post-AMARS; however, AR, AS, CR and CS were not significant predictors of post-AMARS (Table 27). A high degree of reliability (ICC = 0.05) (Appendix M) was found between AMARS measurements. In "Estimates of Fixed Effects" (Table 26), a linear mixed model still gives the significant p-value (<0.000) in only pre-AMARS. Once accounting for the repeated-measure correlation within group, the fixed effects were reduced from significant to not-significant of IBL. Therefore, there was no evidence to reject the null hypothesis in students' AMARS between LCM and IBL for students with different learning styles defined by Gregorc over the 15-academic weeks. The MA levels of the students who learned math under the IBL instruction were reduced, however, there were no particular learners (defined by Gregorc's) who tended to reduce their MA levels under either instructional approach over the 15 academic weeks.

Table 26. Estimates of Fixed Effects for the AMARS with Gregorc's thinking styles (n = 185)'

Variable	Coefficient	Standard. Error	t-value	Pr > |t|
Intercept	1.1719	0.2174	5.3898	<.0000
Pre-AMARS	0.6041	0.0608	9.927	**<.0000**
IBL	-0.2965	0.1463	-2.0263	**0.0773**
AR	0.1453	0.1565	0.9281	0.3546
AS	0.1535	0.1943	0.7898	0.4307
CR	-0.1427	0.1860	-0.7670	0.4441
CS	-0.0632	0.1657	0.3812	0.7035

Note. There is no significant difference in AMARS among students with different learning styles except Pre-AMARS, and IBL in a linear mixed model.

The same tests with Gregorc's thinking styles were run for each of the subscales of AMARS (TA, NA, and MCA), with similar results except MCA. There was no sufficient evidence to reject null hypothesis in students' TA and NA, for students with different thinking styles defined by Gregorc over the 15-academic weeks (Appendix N).

A multiple linear regression was used to predict post-MCA based on pre-MCA, IBL and Gregorc's thinking styles, where there was a significant regression equation (F = 21.009, p-value =0.000), with an R^2 of 0.415. About 41.5% of the variation in the post-MCA is explained by pre-MCA, IBL, and one of Gregorc's thinking styles, CR, for students' MCA (Table 27). Pre-MCA, IBL, and CR were significant predictors of post-MCA; however, AR, AS, and CS were not significant predictors of post-MCA. A high degree of reliability (ICC = 0.18) was found between MCA measurements. In "Estimates of Fixed Effects" (Table 27), a linear mixed model gives the significant p-value (<0.10) in pre-MCA (<0.000), IBL (p-value = 0.0670), and CR learning style (p-value = 0.0844). Table 35 shows that, on average, MCA levels dropped by 0.3924 when CR learning style students had classes with IBL over the 15 academic weeks. Therefore, there was sufficient evidence to reject the null hypothesis in students' MCA between LCM and IBL for students with different thinking styles (CR) defined by Gregorc over the 15-academic week.

Table 27. Estimates of Fixed Effects for the MCA (n = 185)

Variable	Coefficient	Standard. Error	t-value	Pr > |t|
Intercept	1.2118	0.2209	5.0816	<.0000
Pre-MCA	0.5896	0.0601	9.7988	**<.0000**
IBL	-0.3689	0.1741	-2.1185	**0.0670**
AR	0.0883	0.1908	0.4632	0.6438
AS	0.0479	0.2380	0.2013	0.8406
CR	-0.3927	0.2262	-1.7359	**0.0844**
CS	0.0641	0.2033	0.3153	0.7529

Note. There is significant difference in MCA with the significant factor of Pre-MCA, IBL, and CR thinking style in a linear mixed model.

To summarize, the results from the research question 2 with Gregorc's thinking styles demonstrate that there were no significant differences in AMARS, TA, and NA for students with AR, AS, and CS thinking styles during the 15 academic weeks of IBL; however, there was a low significant difference in MCA for students with CR thinking styles during 15 academic weeks of IBL. The results of research question 2 with Gregorc's thinking styles suggest that teaching styles can help alleviate anxiety, but students' thinking styles, as an entire construct, appear to be less related to MA.

Furthermore, the researcher answered the research question 2 with selected Gregorc's thinking styles. For example, given the students with only AR learning styles (n = 56), the post-AMARS decreased by 0.3665 points (p-value = 0.0447) when they took classes with IBL over the 15 academic week; given the students with only AR learning styles (n = 56), the post-TA also decreased by 0.4201 (p-value = 0.0352); given the students with only CS learning styles (n = 44), the post-MCA decreased by 0.8356 (p-value = 0.0115) (Appendix O). The analysis with selected samples of thinking styles shows that AR and CS thinking style learners in IBL reduced their MA by learning through student-centered learning approaches. This finding coordinates with the result of “Estimates of Fixed Effects” (Table 27) that the MCA levels of CR learners were reduced with IBL over the 15 academic weeks. Specifically, in Figure 19 and 20, the time line of Gregorc’s thinking styles in MCA are also evident that the MCA levels of CR learners in IBL were sharply reduced compared to the MCA levels of CR in LCM. These findings may be further investigated in future studies about whether students with particular thinking styles (AR and CS) are more likely to reduce their MA levels in a student-centered learning environment.

Additionally, in both LCM and IBL, each student was identified as having one of the learning styles (by Kolb) and one of the thinking styles (by Gregorc). The researcher analyzed the combination of each student’s learning and thinking styles in LCM and IBL to see whether there were any corresponding patterns between Kolb’s learning and Gregorc’s thinking styles. In LCM, about 11% of students had a combination between ‘converger’ and ‘AR’ learners as a highest percentage combination over the semester, but, as evident in Table 28, there was no meaningful association between learning and thinking styles; both ‘converger’ and ‘AR’ learners did not significantly reduce their MA in LCM (Figure 21). In IBL, about 11% of students had a combination between ‘diverger’ and ‘AR’ learners as the highest percentage combination over the semester, but there was no connection between learning and thinking styles (Table 29); both ‘diverger’ and ‘AR’ did not significantly reduce their MA level in IBL (Figure 22). These results suggest that there were no corresponding learning types between Kolb’s learning and Greogorc’s thinking styles, which also helps justify the exploration of both in this study.

Table 28. Combination of learning and thinking styles in LCM

LCM	Diverger	Assimilator	Converger	Accommodator	K-Flexible	Total
AR	6 (7%)	3 (3%)	**10 (11%)**	7 (8%)	2 (2%)	28
AS	0 (0%)	1 (1%)	4 (5%)	5 (6%)	0 (0%)	10
CR	3 (3%)	3 (3%)	1 (1%)	4 (5%)	2 (2%)	13
CS	6 (7%)	2 (2%)	2 (2%)	7 (8%)	3 (3%)	20
G-Flexible	4 (5%)	2 (2%)	5 (6%)	2 (2%)	4 (5%)	17
Total	19	11	22	25	11	88

Note: each participant was identified as having one of the learning styles (by Kolb) and one of the thinking styles (by Gregorc) in LCM

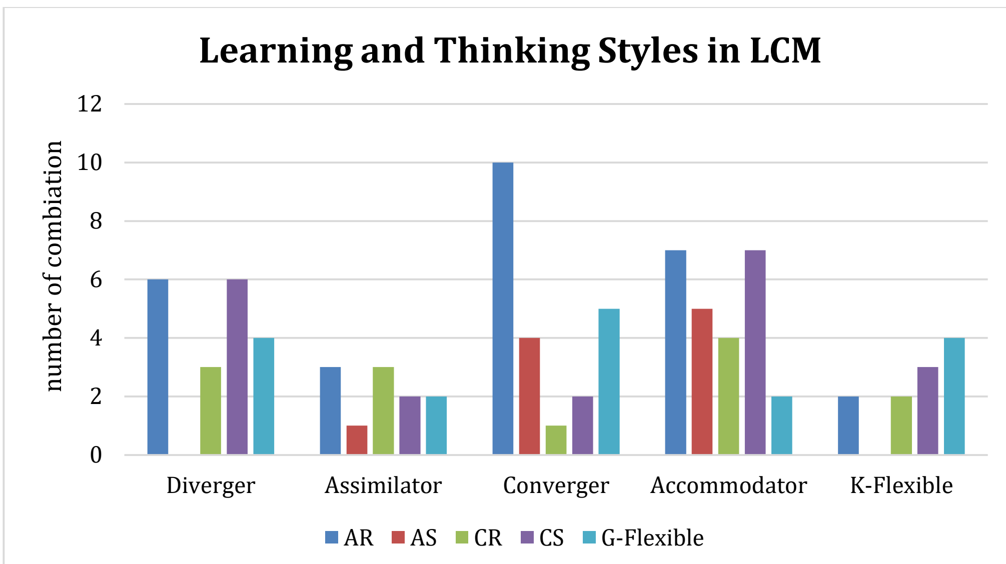


Figure 21. A graph of students' learning and thinking styles in LCM

Table 29. Combination of learning and thinking styles in IBL

IBL	Diverger	Assimilator	Converger	Accommodator	K-Flexible	Total
AR	**11 (11%)**	6 (6%)	4 (4%)	4 (4%)	3 (3%)	28
AS	3 (3%)	5 (5%)	2 (2%)	3 (3%)	1 (1%)	14
CR	6 (6%)	2 (2%)	4 (4%)	2 (2%)	1 (1%)	15
CS	6 (6%)	5 (5%)	7 (7%)	3 (3%)	3 (3%)	24
G-Flexible	6 (6%)	2 (2%)	2 (2%)	6 (6%)	0 (0%)	16
Total	32	20	19	18	8	97

Note: each participant was identified as having one of the learning styles (by Kolb) and one of the thinking styles (by Gregorc) in IBL.

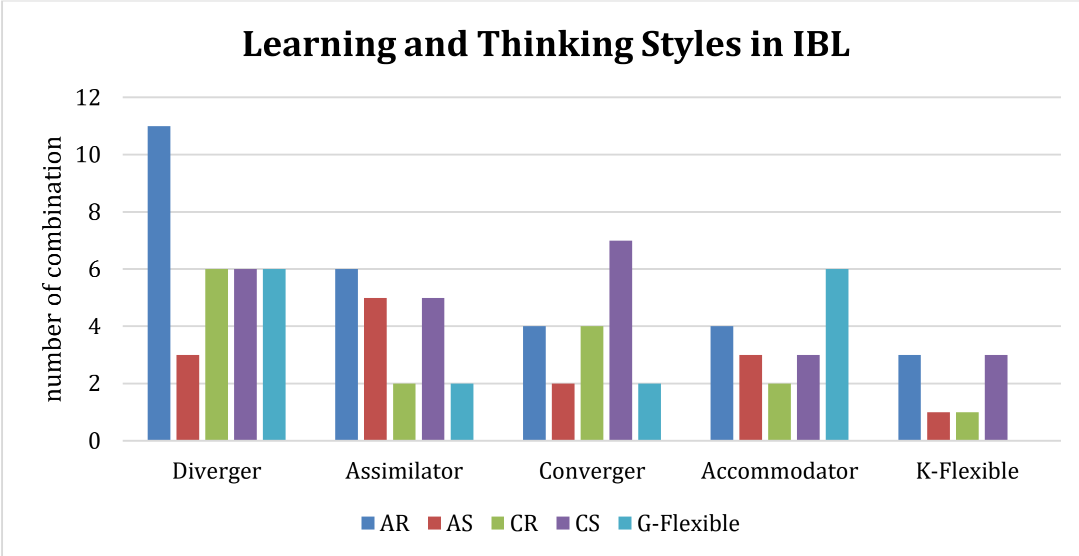


Figure 22. A graph of students' learning and thinking styles in IBL

Qualitative Data Analysis

In order to answer the third research question, the researcher gave and collected open-ended questionnaires which allowed participants to describe their experiences. In order to analyze the data, the researcher used the basic principles of the grounded theory method (Strauss & Corbin, 1990); i) finding repeating keywords and phrases, ii) grouping the keywords and phrases based on the emergent themes, and iii) theorizing the relationship of the generated themes. By sorting the data, the results of these questionnaires informed the researcher about the factors of students' MA in LCM and IBL, or their reaction to instructional style over the course of the semester.

Research Question 3.

At the end of the semester, there were 28 participants who wrote responses of varying lengths about how they had personally experienced MA. Out of 28 participants, 16 students were in LCM, and the other 12 students were in IBL. The written questionnaire consisted of eight items, and questions were organized into four themes related to MA: factors of MA (item 1), instructor's teaching style in reducing or decreasing their MA (items 2 to 4), and their preferred teaching style with MA (items 5 to 7). The responses of the 28 participating students were analyzed using grounded theory (Strauss & Corbin, 1990) and guided by the following research question: What aspects of instructional approaches (LCM and IBL) do students with different learning and thinking styles report as being related to mathematics anxiety? This question sought to determine whether the influence of a teacher's instructional style increased or decreased students' MA levels throughout the semester. Table 30 shows participants who completed a written questionnaire in LCM and IBL at the end of the semester.

Table 30. Description of twenty-eight participants' DMARS, DTA, DNA, DMCA and learning styles in a written questionnaire

Class Model	participants	Instructor	DAMARS	DTA	DNA	DMCA	Learning Style (Kolb /Gregorc)
IBL	I1	BB	3.56	3.27	4	4	Flexible / CS
	I2	BB	-.4	-.34	-.6	-.4	Converger/ CS
	I3	BB	-.96	-1.2	-1	-.2	Assimilator/G-flexible
	I4	DW	-.24	.14	-.6	-1	Diverger /AR
	I5	DW	-1.08	-1.6	-0.4	-.2	Converger/ CR
	I6	JJ	-1.76	-1.53	-2.4	-2	Diverger / G-flexible
	I7	JJ	-1.28	-1.33	-.8	0	Accommodator/ AS
	I8	TT	-1.56	-.67	-2	-3.8	Accommodator/ CR
	I9	TT	-.55	-.86	-.2	0	Accommodator / G-flexible
	I10	LL	-.64	-.93	-.4	0	Diverger /AR
	I11	LL	-.36	-.46	-.2	-.2	Accommodator / G-flexible
	I12	LL	-1.84	-1.53	-2.4	-2.2	Diverger /CR
LCM	L1	CC	2.62	1.93	3.75	3.6	Flexible /AR
	L2	CC	0.32	-.2	.8	1.4	K- flexible / G-flexible
	L3	JO	2.44	2.33	1.6	3.6	Accommodator /AR
	L4	JO	.04	-.07	0	.4	Accommodator/AR
	L5	JO	-.36	-.14	-1.2	-.2	Assimilator / G-flexible
	L6	CC	.44	.6	0	.4	Diverger /AR
	L7	DD	-.12	-.14	-.2	0	Converger/ AR
	L8	DD	.4	1.32	-.4	-1.4	Diverger/ AR
	L9	DD	.88	.67	1.4	1	Converger/ AR
	L10	LO	.24	.2	-.2	.8	Assimilator /AS
	L11	LO	0	-.33	.2	.8	Converger/ AR
	L12	LO	-.99	-.91	-1.2	-1	Assimilator /CS
	L13	LO	-.04	-.06	0	0	K-flexible / G-flexible
	L14	SS	-.07	-.11	0	0	Converger/ AR
	L15	SS	.84	1.34	0	.2	Accommodator/ CR
	L16	SS	-.64	0	-1.6	-1.6	Converger/ AR

Note. Flexible is an indicator that students belonged to more than two learning styles by Kolb’s or thinking styles by Gregorc’s. DAMARS, DTA, DNA, and DMCA represent the difference between post-and pre-AMARS, TA, NA, and MCA over the 15 academic weeks.

Theme 1: Factors causing mathematics anxiety. MA is not only caused by low mathematics ability, but it is also caused by negative attitudes, cognitive factors, assessment in a mathematics classroom, self-efficacy, gender, emotion, social factors (Dowker, Sarkar, & Looi, 2016). In the written questionnaire, the following question was asked regarding these factors: Did you experience MA during the 15 weeks of the semester? If so, please explain what you think contributed to feeling of MA. Six common factors were found after analyzing the 28 participants' responses. (Table 31).

Table 31. Theme 1. Factors of mathematics anxiety

1Ta.	Low Self-efficacy
1Tb.	Mathematical difficulty (homework, terminology, formula, new learning…etc.)
1Tc.	Pressure of exams
1Td.	Teacher's teaching style
1Te.	Individual learning styles
1Tf.	Technology Integration classroom (Web-based Instruction, or WeBWork)

Note. There are six factors causing of mathematics anxiety. Each 1Ta through 1Tf represents the code of contributing factors to MA.

Twenty-eight participants were asked whether they had experienced MA during the semester. If they did, they elaborated on the feelings of their MA and the factors they associated with their MA. After the participants completed the written questionnaire, the researcher created six contributing factors of MA based on the keywords under theme 1. Two students in LCM reported that they did not experience MA, and the other 26 students who had experienced MA revealed different factors of their MA. Table 32 shows the number of students who corresponded to each factor: low self-efficacy, mathematics difficulty, the pressure of exams, teachers' teaching style, individual learning style, and lack of technology skills.

Table 32. Twenty-eight participants in LCM and IBL under theme 1.

		LCM		IBL	
Code	**Factors of MA**	**# of participants**	**Participants' Learning and Thinking Styles**	**# of participants**	**Participants' Learning and Thinking Styles**
1Ta	Low Self-efficacy	2	L1 (K-Flexible/AR) L13 (K-flexible/G-flexible)	0	np
1Tb	Mathematical difficulty	6	L2 (K-flexible/G-flexible) L3 (Accommodator/AR) L6 (Diverger/AR) L8 (Diverger/AR) L11 (Converger/AR) L15 (Accommodator/CR)	3	I2 (Converger/CS) I4 (Diverger/AR) I8 (Accommodator/CR)
1Tc	Pressure of exams	3	L7 (Converger/AR) L10 (Assimilator/AS) L14 (Converger/AR)	3	I3 (Assimilator/G-flexible) I7 (Accommodator/AS) I12(Diverger/CR)
1Td	Teacher's teaching style	2	L4 (Accommodator/AR) L5 (Assimilator/G-flexible)	1	I1 (K-flexible/CS)
1Te	Individual learning styles	1	L12 (Assimilator/CS)	2	I5 (Converger/CR) I6 (Diverger/G-flexible)
1Tf	Lack of technology skills	0	np	3	I9 (Accommodator/G-flexible) I10 (Diverger/AR) I11 (Accommodator/G-flexible)
	No response	2	L9 (Converger/AR) L16 (Converger/AR)	0	np
	Total	16		12	28

Note. np stands for not countable

Low self-efficacy with mathematics anxiety (1Ta). Only two students in LCM mentioned that a factor of MA was related to low self-efficacy. In mathematics, anxiety, self-efficacy and the belief in his or her inability in mathematics are affective traits possessed by an individual (Philipp, 2007). Mathematical self-efficacy can be defined as one's capability or confidence to organize and attain the designated type of mathematical performance or task (Bandura, 1997). Self-efficacy has been reported to affect the academic achievement of students, and there is a positive correlation between self-efficacy and students' academic performance (Ashcraft & Kirk, 2001; Luigi et al., 2007). The following are students' responses of self-efficacy:

I had a hard time understanding concept no matter how they were explained to me. It made me feel pretty dumb, and I wanted to give up the rest of class... (student in LCM – LO –L13).

Yes. I had experience in math anxiety. Math is my biggest academic weakness. It makes me feel frustrated, and I got migraines in every class. I may not pass the course. (student in LCM – CC – L1).

These students were not motivated to learn mathematics and felt that they were not able to learn mathematics due to their lack of confidence completing mathematics problems. This state of anxiety leads to forgetfulness and causes the individual to lose confidence (Tobias, 1993). Even though there were resources available such as daily practice and, tutoring, they believed that these were not helpful in reducing their anxiety level. They also were not willing to overcome difficulties or obstacles in solving mathematics problems. Such a belief negatively affected their academic performance on mathematical tasks.

Mathematical difficulty with mathematics anxiety (1Tb). Six students in LCM and three students in IBL stated that they experienced MA over the 15 academic weeks due to mathematical difficulties including completing assignments, learning in a new environment, getting a wrong answer, or not knowing how to solve a problem. Feelings of MA are experienced whenever a person is confronted with a mathematical situation. This situation can come from being in a mathematics classroom, working on homework, learning a new mathematics concept, getting wrong answers, or facing difficulties in mathematics problems (Ashcraft, 2001; Tobias, 1980). Two participants discussed how he/she experienced difficulties in a mathematics classroom.

Sometimes because I think that the assignments are challenging for me to finish myself at home. I think that some questions in the homework are difficult for me. I think that the limit times to finish the quiz makes me frustrated (student in LCM – CC - L3)

Yes. I experience math anxiety. I am always nervous in this class. Stepping into something that I was not familiar makes me anxious. Especially, I do not enjoy solving a new math problem (student in LCM – SS – L15)

Students showed that MA could be caused by tension and stress as they were solving problems or performing mathematics problems with numbers in both school and everyday life (Tobias, 1993). Those students stated that their anxiety increased based on the tension and stress from incomplete assignments, new concepts, and lack of understanding on how to solve assignments or classwork in and outside of the classroom.

Final exam and mathematics anxiety (1Tc). Three students in LCM and the other three students in IBL stated that their MA was related to taking an exam. Mathematics test anxiety is a severe and pervasive problem, especially with community college students. The students who were taking the last level of remedial mathematics courses (MAT 56) had more pressure than the students in other remedial courses to pass the final exam. Based on the school policy, students were allowed to enter a credit-bearing course after they passed the final exam in MAT 56. Therefore, the participants had more pressure and anxiety in taking quizzes, and midterm and final exams that were reflected in their final grade. As illustrated by the following;

I felt fine for the most part. However, I felt anxiety during the last few weeks because the final exam is around the corner. (student in LCM – DD –L7)

Based on my exam score, Math is my weakest subject, and this course is challenging. Luckily, I was able to understand the lessons and do the work, but the exams affected me tremendously. I feel I always unprepared for the exam… (student in IBL – LL – I12).

Most students found themselves blanking out on mathematics tests, even though they understood the material, were able to do homework and had prepared for the exam. Some students who usually did not have MA over the semester started feeling MA when they faced the final exam.

For those students, the mathematics exam was considered a do-or-die challenge that brought frustration to the mathematics classroom.

Teaching style and mathematics anxiety (1Td). Two students in LCM and one student in IBL stated that teaching styles were related to their MA. This includes teachers' actions such as lecturing too quickly, unclearly explaining, not helping an individual student, and requiring students to participate on the board and memorize formulas and terminology. The previous literature review showed a relationship between a teacher's instruction and the MA of their students, which implies that teachers can have both positive and negative effects on students' MA. Teaching style, instruction, and teachers' beliefs, and teachers' attitudes have different effects on students' achievement and their MA as well (Darling-Hammond, 2004). The following responses show how teaching styles impacted participants' MA.

> With professor, he explains things in a complicated way, and he told us that we could not ask him questions it makes me feel anxiety (student in LCM – JO – L4).

> Yes. I experienced some math anxiety this semester. I think that the factor of my feelings was keeping up with all the terminology and formulas and also the pressure of getting a score of B or higher in order to get into a program. I wonder if there is another way to learn math not using formula or memorizing (student in IBL – BB-I1).

These students stated that an instructor's particular teaching styles, which included in this case, requiring the student to memorize a formula and terminology, and giving an unclear explanation, contributed to their MA.

Learning style with mathematics anxiety (1Te). One student in LCM and two students in IBL stated that their learning style was related to MA. Few research studies have examined learning style and MA, but it is crucial for teachers to be concerned about the effects of students' learning styles on MA. In a recent study, Esa and Mohamed (2017) identified the relationship between students' learning styles, as defined by Grasha (1996), and their MA. They found that the majority of the students adopted a collaborative learning style and the students had a moderate level of MA. In this study, Kolb's and Gregorc's learning styles were used, and two students mentioned that they experienced MA since they have a particular learning style in learning mathematics.

> Yes, I had experience in math anxiety. I believe because it takes me a little more time to understand concepts…There were many criteria to cover myself so I had to go too fast for my specific way of learning (student in LCM – LO – L12)

> Yes. The new environment such as using a computer makes me uncomfortable. Especially, I like doing problems on paper rather than a computer. I don't like online resources (student in IBL – DW – I5).

These students believed that their learning style was a strong predictor of their MA. They stated that knowing their learning style might be a problem with respect to MA.

Lack of technology skills (1Tf). In this study, since the online assignment software WeBWork was used only in IBL, only three students in IBL stated that lack of their technology skills was related to their MA. In general, web-based instruction is used to connect students, peers, and instructors via technological media (Greene & Meek, 1998). Although there are many benefits of using web-based instruction in mathematics, there are several disadvantages. For example, students who are not self-motivated, self-directed and independent may have trouble completing online assignments on their own. Some students may lose motivation due to specific deadlines by which they must complete given assignments. Moreover, when students are completing an online assignment, there is little human interaction. As a result, students have a harder time asking a question when they are faced with a difficult problem. Four participants responded that using web-based assignments on WeBWork produced more anxiety, especially in working on WeBWork online assignments by themselves at home.

> Yes. I found that the wording of the problems was confusing on the WeBWork. I used WeBWork to do my homework, but I do not know how to solve the problem when I am doing it myself... The professor should not just say 'use WeBWork' to practice more problems because most of the work was based on the WeBWork homework that I do not understand how to solve… (student in IBL – TT – I9).

The students who responded about MA in relation to WeBWork were in IBL classes. In this study, the instructors in IBL were trained in web-based instruction during the semester; however, students felt isolated from the instructor when they needed to complete a WeBWork assignment by themselves on time, which contributed to their MA.

Theme 2: Instructor's teaching style in reducing students' MA. The researcher observed 1Td in Theme 1 more carefully in each LCM and IBL with the detailed responses of participants**.** In many studies, the teacher's instruction influences students' learning experience in mathematics and their MA level (Darling-Hammond, 2004; Hembree, 1990). Therefore, students' responses in both LCM and IBL were different since the teaching styles between LCM and IBL were different. Moreover, as the researcher analyzed her observations of 10 different classes in the previous field notes, different teaching strategies in LCM and IBL were identified. There were 28 participants who were asked whether their instructor had an aspect of their teaching style that helped reduce their MA during the semester. If they did, they elaborated on their instructors' teaching styles. In the written questionnaire, the following question was asked regarding instructor's teaching styles: Please explain anything about the instructor's teaching style that helped reduce your feelings of MA. In order to analyze their responses, three different contributing components were considered under the second theme: 2a) teachers' feedback, comment or positive influence, 2b) instructor's explanation, and 3c) instructor's material (Table 33).

Table 33. Theme 2. Instructor's teaching style in reducing students' mathematics anxiety in LCM.

2a. Instructor' feedback, comment, or positive influence
2b. Instructor's explanation
2c. Instructor's materials (paper or PowerPoint)

About 56% of students in LCM stated that the teacher's clear explanations helped them reduce their MA. About 30% of student in LCM also mentioned that the teacher's positive feedback helped them with their MA (Table 34).

She was pretty good at explaining what is what. However, sometimes the rushing through examples gets confusing. Step-by-step explanation with the reason why that step is being done helps me (student in LCM – CC – L2)

I like how she explains everything and sent us the slides and materials helps students who are lost in class to go home and receive what they learned today (student in LCM – DD – L7)

Table 34. Participants in LCM under Theme 2.

		LCM	
Code	**Instructor's Teaching Style in reducing MA**	**The # of students**	**Participants' Learning and Thinking Styles**
2a	Instructor's positive feedback and comment	5 (30%)	L3 (Accommodator/AR) L4 (Accommodator/AR) L11 (Converger/AR) L16 (Converger/AR)
2b	Instructor's explanation in class	7 (44%)	L1 (K-flexible/AR) L2 (K-flexible/G-flexible) L6 (Diverger/AR) L7 (Converger/AR) L8 (Diverger/AR) L10 (Assimilator/AS) L13 (K-flexible/G-flexible)
2c	Instructor' study aid	4 (25%)	L5 (Assimilator/G-flexible) L9 (Converger/AR) L12 (Assimilator/CS) L15 (Accommodator/CR)
	No response	0	n/p
	Total	16	

In general, there is critical discussion about step-by-step strategies or procedural literacy in teaching mathematics (Shellard & Moyer, 2002). With an instructor's decontextualized step-by-step explanation, students tend to sit for a long-time taking notes focusing on procedural concepts rather than conceptual fluency. However, more than half of the students in LCM stated that the teacher's step-by-step explanation, or watching how she or he solved the algebraic problem, helped reduce their MA over the semester. Rittle-Johnson and Alibali (1999) investigated the relationship between conceptual and procedural knowledge in learning, and they suggested that conceptual knowledge influences procedural knowledge and vice versa. In LCM, students considered that a lack of procedural fluency could contribute to a lack of conceptual understanding. Since most students in LCM had many concerns about making algebraic mistakes in their work, they emphasized how to perform procedures accurately by understanding the teacher's skills. Therefore, watching the instructor's step-by-step work was an important part for them to understand how to write and develop mathematical fluency, which related to their MA.

In IBL, three other different contributing components were considered under the second theme: 2d) instructor's explanation, 2e) group work and 2f) instructor's material including open educational resources (Table 35).

Table 35. Theme 2. Instructor's teaching style in reducing students' mathematics anxiety in IBL.

2d. Instructor's feedback and comment
2e. Group work
2f. Instructor's materials (open educational resources)

About 33% of students in IBL also mentioned that the teacher's positive feedback and comments helped them with their MA. About 42% of students in IBL stated that working with other students helped them reduce their MA. (Table 36)

Praising such as "you got this" "you are doing good" from my tutor and professor made me less anxious (student in IBL – BB – I3).

Visually seeing how to solve the problems in a group made it easy to understand the material. Later, I was also able to solve on my own (student in IBL – DW –I4).

Table 36. Participants in IBL under Theme 2.

	IBL		
Code	**Instructor's Teaching Style in reducing MA**	**The # of students**	**Participants' Learning and Thinking Styles**
2d	Instructor's feedback and comment	4 (33%)	I3 (Assimilator/G-flexible) I9 (Accommodator/G-flexible) I10 (Diverger/AR) I11 (Accommodator/G-flexible)
2e	Group work	5 (42%)	I1 (K-flexible/CS) I2 (Converger/CS) I4 (Diverger/AR) I8 (Accommodator/CR) I12 (Diverger/CR)
	Instructor's study aid	2 (25%)	I5 (Converger/CR) I6 (Diverger/G-flexible)
	No response	1	I7 (Accommodator/AS)
	Total	12	

Many researchers reported that teachers who implement student-centered instruction or growth mindset assessment could help students reduce MA (Boaler, 2016; Sparks, 2015). Teachers who respond to incorrect answers with positive feedback, let students know that mistakes are okay, and reward individual effort instead of praising only mathematics achievement can help students participate in the class with less MA. In IBL, showing a positive attitude, and giving praise or extra time to students, encourages students to believe that they have the ability to problem solve in any mathematical situation. In addition, instructional pedagogies such as group work allowed students to reduce their MA. About 42 % of students agreed that their MA was reduced when the teacher utilized a student-centered instruction where students felt that they were able to set goals for themselves so that they could build both their self-confidence and learning skills. With collaboration, group work, and the teacher's dedication to a clear explanation of the lesson, students had ownership in their learning and made their own decisions during mathematics problems. Specifically, in group work, students in IBL had the opportunity to engage with other students. This "human contact" component of teaching between teacher and students or among peers led students to feel comfortable while they were acquiring mathematical knowledge with less MA. The diverse components of student-centered instruction helped students to be motivated in controlling their learning by gaining confidence, managing their learning pace, and measuring their achievement.

The students in both LCM and IBL felt that they were engaged with their learning more based on teachers' positive feedback with less MA no matter what the classroom model was. Teachers' comments or their encouragement had an impact on the interest, performance, and attitude of students with the effect of reduced MA.

Theme 3: Instructor's teaching style in increasing students' MA. In his study, Blazer (2011) argued that instruction that increases students' MA includes little clarification on what is being taught, formula-based teaching, and memorization. In addition, teachers' deficient knowledge in explaining concepts, poor time management, lack of patience needed to answer questions, and lack of feedback that might intimidate students from asking questions contributes to students' MA. Instead of showing students the concepts behind a formula, a teacher who focuses on memorization can increase students' MA. In LCM, three students' answers were categorized around a similar theme, and the three main different contributing components were considered under the third theme: 3a) formula and memorization, 3b) teacher's deficient explanation, 3c) not enough time in problem-solving, and 4) nothing (Table 37).

Table 37. Theme 3. Instructor's teaching style in increasing students' mathematics anxiety in LCM

3a. Formula and memorization
3b. Teachers' deficient explanation
3c. Not enough time in problem-solving
3d. nothing

About 50% of students in LCM stated that there was nothing in their teacher's instructional styles that increased their MA. About 17% of students stated that the teacher's poor time management increased their MA (Table 38).

Sometimes, I would feel rushed to finish a problem in class on a test that would make me anxious (student in LCM – CC – L2).

The instructor does not give enough and clear handout or instructions. She is very lenient about the class (student in LCM – DD – L7).

Table 38. Participants in LCM under Theme 3

LCM			
Code	**Instructor's teaching style in increasing MA**	**The # of students**	**Participants' Learning and Thinking Styles**
3a	Formula and memorization	1 (6 %)	L1 (K-flexible/AR)
3b	Teacher's deficient explanation	2 (12 %)	L3 (Accommodator/AR) L7 (Converger/AR)
3c	Poor time management	5 (17 %)	L2 (K-flexible/G-flexible) L4 (Accommodator/AR) L8 (Diverger/AR) L9 (Converger/AR) L12 (Assimilator/CS)
3d	Nothing	8 (50%)	L5 (Assimilator/G-flexible) L6 (Diverger/AR) L10 (Assimilator/AS) L11 (Converger/AR) L13 (K-flexible/G-flexible) L14 (Converger/AR) L15 (Accommodator/CR) L16 (Converger/AR)
	Total	16	

In IBL, three different contributing components were considered under the third theme: 3a) formula and memorization, 3b) a teacher's less explanation, 3c) poor time management, 4) nothing (Table 39).

Table 39. Theme 3. Teaching style in increasing students' mathematics anxiety in IBL

3a. Formula and memorization
3b. Teachers' lack of explanation
3c. Not enough time in problem-solving
3d. nothing

About 33% of students stated that the teacher's lack of explanation increased their MA. About 25% of students stated that lack of time in problem-solving increased their MA (Table 40).

Sometimes, the material was explained to rush. By the time I copied everything she was explaining, and I was busy coping so I would miss information (student in IBL – JJ – I6).

Formula! Similar examples that I do not understand cause me to have more anxiety (student in IBL – LL –I10).

Similar to LCM, students' feelings of MA were increased when they did not have enough time to think or solve the problems. Moreover, the teachers in IBL were trained to lecture less, implying that students were supposed to discover or construct their ideas. However, the teacher's lack of explanation caused some students' MA while the instructor was expecting to see students' engagement with their materials.

Table 40. Participants in IBL under Theme 3

	IBL		
Code	**Instructor's teaching styles in increasing MA**	**The # of students**	**Participants' Learning and Thinking Styles**
3a	Formula and memorization	1 (8 %)	I10 (Diverger/AR)
3b	Teacher's lack of explanation	4 (33 %)	I4 (Diverger/AR) I5 (Converger/CR) I7 (Accommodator/AS) I11 (Accommodator/G-flexible)
3c	Not enough time in problem-solving	3 (25 %)	I1 (K-flexible/CS) I2 (Converger/CS) I6 (Diverger/G-flexible)
3d	Nothing	4 (33 %)	I3 (Assimilator/G-flexible) I8 (Accommodator/CR) I9 (Accommodator/G-flexible) I12 (Diverger/CR)
	Total	12	

Theme 4: Preferred teaching styles. Students' preferences in learning mathematics courses are important because they may find their ability to learn best through preferred instructional

approaches. In the written questionnaire, students were asked how they learn mathematics best, what kinds of teaching styles they prefer, and which activities they prefer in the mathematics classroom. The students' responses were analyzed to find similar components in both LCM and IBL. In LCM, three different contributing components were considered under the fourth theme: 4a) the detailed explanation, 4b) practice with the professor, and 4c) work with peers (Table 41).

Table 41. Theme 4. Participants' preferred teaching styles in LCM

4a. The detail explanation
4b. Practice with professor
4c. Work with peers

More than half of students in LCM responded that they learned best when they practiced problems that they learned during the class session with the professor (Table 42).

I prefer present professor because, in each step, he goes slowly so that I fully understand what the question is asking (student in LCM – JO –L4).

I learn math best by doing practice problems. It helps me retain what I learned and prevent me from forgetting (student in LCM – DD – L8).

Table 42. Participants in LCM under Theme 4

		LCM	
Code	**Preferred Teaching Style**	**The # of students**	**Participants' Learning and Thinking Styles**
4a	The detail explanation	2 (13 %)	L1 (K-flexible/AR), L4 (Accommodator/AR)
4b	Practice with Professor	9 (56 %)	L2 (K-flexible/G-flexible), L3 (Accommodator/AR) L5 (Assimilator/G-flexible), L6 (Diverger/AR) L8 (Diverger/AR), L11 (Converger/AR) L12 (Assimilator/CS), L13 (K-flexible/G-flexible) L16 (Converger/AR)
4c	Work with peers	3 (19 %)	L7 (Converger/AR), L10 (Assimilator/AS) L14 (Converger/AR)
4d	Others	2 (13 %)	L9 (Converger/AR), L15 (Accommodator/CR)
	Total	16	

The students stated "practice" and "explain" commonly in their responses, implying that they had been used to being in LCM where the instructors showed step-by-step or procedural fluency in problem-solving. This implies that students had adapted to the lecture style, either over the 15 academic weeks or from previous experiences in mathematics classes, and they had understood how to study in LCM.

In IBL, three other different contributing components were categorized under the fourth theme: 4e) work with others in a group, 4f) practice problems and 4g) conceptual understanding (Table 43).

Table 43. Theme 4. Participants' preferred teaching styles in IBL

4e. Work with others in a group
4f. Practice problem
4g. Conceptual understanding.

About 42% of students in IBL stated that they preferred to learn with others in a group or doing another group activity. About 33% of students preferred the teaching style of practicing problems with either the professor or other students (Table 44).

> The best way to do math is hands on. By this, I mean doing practice problems on paper with others (student in IBL – DW –I5).

> By watching others and doing the examples a few different times, trying a few more on my own. Then reviewing my work with the teacher or others (student in IBL – BB –I1).

Table 44. Participants in IBL under Theme 4

IBL			
Code	**Preferred Teaching Style**	**The # of students**	**Participants' Learning and Thinking Styles**
4e	Work with others in a group	5 (42%)	I1 (K-flexible/CS) I3 (Assimilator/G-flexible) I6 (Diverger/G-flexible) I7 (Accommodator/AS) I10 (Diverger/AR)
4f	Practice problems	4 (33 %)	I4 (Diverger/AR) I8 (Accommodator/CR) I9 (Accommodator/G-flexible) I11 (Accommodator/G-flexible)
4g	Conceptual understanding	2 (17 %)	I2 (Converger/CS) I5 (Converger/CR)
4h	Others	1 (8%)	I12 (Diverger/CR)
	Total	12	

Since IBL included more group work and classroom activities than LCM, students' preference for teaching styles were categorized differently. However, the participants in both LCM and IBL preferred to have more practice with the professor or other students to improve their understanding of problem-solving.

CHAPTER V

SUMMARY, CONCLUSION, RECOMMENDATION

Summary

Mathematics anxiety (MA) has been an issue in mathematics education for quite some time, and students with MA struggle on numerical tasks and with performance in general, which are linked to developing mathematical knowledge. According to the Program for International Student Assessment (PISA) studies, many young adults reported that they have worries and tensions when doing mathematics or being in a mathematics classroom (OECD, 2013). Different factors cause the development of MA: there are individual influences such as self-efficacy, prior-experience in mathematics, learning style, and cognitive processing; teacher influence such as teacher's instruction, and beliefs and attitudes: and societal influence such as parents' attitudes toward their children's ability in mathematics and stereotypes between males' and females' mathematics abilities. These contributing factors influence many variables important in students' learning processes.

In an educational setting, MA has an adverse effect on mathematics achievement. The most commonly known hypothesis for the relationship between MA and mathematics achievement is that MA leads to negative attitudes toward mathematics and consumes the capacity of working memory (Ashcraft, 2001). The consumption of working memory capacity inhibits analytical information processing, which negatively influences mathematics achievement. Thus, MA leads to behavior that avoids mathematics, and it directly affects math-related lectures, majors, and mathematics-related career choices. As a result, MA causes economic losses not only at the individual levels but also at the national workforce level (Brunye et al., 2013).

The effect of MA on developmental mathematics courses at an urban community college has been investigated due to students' low passing rate from not only their lack of basic mathematics skills but also nervousness and a feeling of tension with taking a mathematics qualification exam. Specifically, at an urban community college, there is a growing population of students that consist of first-generation college students, English language learners, and students from different racial and ethnic backgrounds who are somewhat skeptical about their chances in college (Richardson & Skinner, 2000). As diverse students enter community colleges, their anxiety tends to be heightened not only due to their unpreparedness for college work, but also their unsuccessful stories in higher-education and future job possibilities as a minority. Thus, this study investigates the impact of instructional approaches and learning styles on MA in the context of an urban community college. First, this study suggests that particular instructional approaches may be part of the reason for MA, and has led to the development of new teaching methods to mitigate students' MA. There have been many attempts to find effective teaching strategies that reduce MA under student-centered teaching methods such as inquiry-based learning where all learning is driven by students' engagement, thoughtful questioning, and teamwork.

Although student-centered learning approaches, including inquiry-based learning, were to be implemented in higher education (Christine & Volker, 2015), the approaches do not reduce all students' MA; individual differences are believed to lead to preferences regarding teaching instruction, types of learning experiences, and preferred classroom environments (Guild, 1994;

Hallett et al., 2012; Siegler, 2013). Many researchers (Guild, 1994; Siegler, 2013) mention that knowing each student, their individual differences and learning styles were essential for facilitating, structuring, and validating successful learning in the classroom for all students, which can reduce students' MA levels. Thus, this study evaluated not only students' MA levels but also their learning styles to see whether an inquiry-based learning approach was beneficial to all students, or only to some particular learners, who were taking the same remedial mathematics course at an urban community college. This study evaluated the influence on MA of different teaching styles interacting with Kolb's (1984) and Gregorc's (1984) different learning and thinking styles.

Conclusions

Research question 1. What is the difference between a lecture classroom (LCM) and an inquiry-based learning classroom model (IBL) on students' MA levels over a fifteen-week semester of a college level remedial mathematics course? The results from research question 1 were that the participants' overall MA levels were significantly different over the 15 academic weeks between the two different teaching models (LCM and IBL). Specifically, there was a significant difference in test anxiety (TA) and mathematics course anxiety (MCA) between pre- and post-survey compared to two different instructional approaches (LCM and IBL) (Figure 23). A statistically significant difference in pre- and post-survey scores in IBL was measured, implying that the students in IBL experienced decreased levels of MA as the semester progressed. On the other hand, students in LCM experienced increased levels of MA as the semester progressed. This study provides evidence that using IBL instruction was beneficial for the students with MA, especially with mathematics test anxiety and mathematics course anxiety. Only numerical task anxiety was not significant, which is comparable to LCM. The result provided interesting findings regarding the teacher's instruction where teacher's perceptions about student-centered learning approaches was statistically related to students' MA levels. That is, student-centered learning pedagogies turned out to be an apparently effective and engaging method for lowering MA. Student-centered learning strategies such as inquiry-based learning, technology-integrated classroom, and active learning of IBL generated an apparent model for reducing students' MA in a community college mathematics classroom.

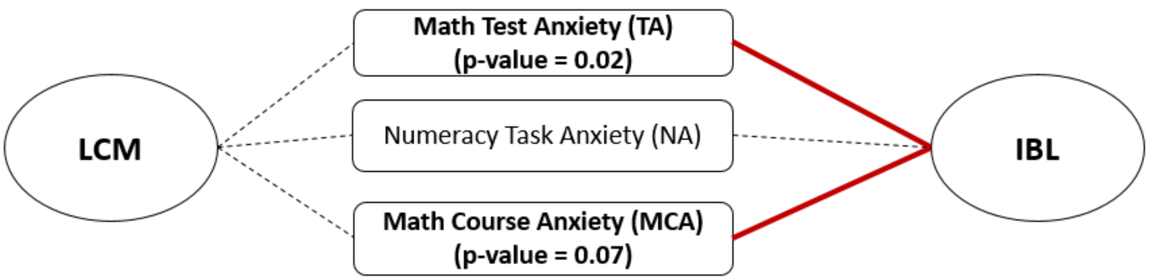


Figure 23. Results of Research Question 1

Note. There was a significant difference in reducing student' MA in Mathematics Test Anxiety and Mathematics Course Anxiety throughout the semester. The bold lines indicate the p-value of Mathematics Test Anxiety was 0.02, and the p-value of Mathematics Course Anxiety was 0.07, which is a statistically significant in this study. Dotted lines show statistical insignificance.

Research question 2. What is the difference between a lecture classroom model (LCM) and an inquiry-based learning classroom model (IBL) on MA levels for students with different learning and thinking style (as defined by Kolb and Gregorc) over a fifteen-week semester? The results from research question 2 with both Kolb's learning styles and Gregorc's thinking styles show that: i) teaching styles were a significant predictor of MA, and ii) learning and thinking styles, as entire constructs, were not a significant predictor of MA, above and beyond the distinction between the two teaching styles. The instructional approaches based on student-centered learning appeared to have a significant influence on reducing students' overall AMARS, TA and MCA. However, there was no evidence to support the relationship between the constructs of learning and thinking styles and MA levels. In other words, understanding students' learning and thinking styles may not be essential if teachers wish to reduce students' MA.

Classifying students according to learning styles (diverger, converger, assimilator, or accommodator) and thinking styles (Concrete Random, Concrete Sequential, Abstract Random, and Abstract Sequential) did not necessarily appear to be associated with students' MA levels in this study. On the whole, there was insufficient evidence to support taking action to build a relationship between learning and thinking styles of learners and their MA levels. The individual investigation of some particular learning and thinking styles in this study suggest that such efforts might not be completely in vain; that is, there may be some aspects of diverger and converger learning styles, and CS and AR thinking styles, that tend to benefit learners in IBL instruction (in comparison with LCM); no types of learners (based on learning and thinking styles), however, were especially benefitted by LCM instruction. Further research into these potential aspects are warranted from this study; however, on the whole, the findings does not suggest a meaningful association with the entire constructs of learning and thinking styles, as defined by Kolb and Gregorc.

The results of this study show a contrast between a general belief about the importance of individual difference and learning styles (e.g., Languis, 1998; Oxford, 1994) and insufficient evidence based on the findings from this study that would warrant this belief (Figure 24). Other researchers (Breuer, 1999; Tarver, 1996) have doubted the existence of a link between instruction and learning style in educational settings because there is the lack of supportive research, questionable validity and reliability of learning and thinking styles inventories, and arguments about the use of learning styles in instruction (Steelwagen, 2001). Specifically, there was no evidence that 'abstract random' learners were cooperative in IBL or that 'diverger' learners were compatible with IBL with respect to their MA levels, as hypothesized from the literature. Instead of focusing so much on learning and thinking styles of individual students, the results of this study indicate that teachers would be better served (regarding MA levels) by focusing on teaching and pedagogical content knowledge based on student-centered instruction for all students, which appear to be more associated with reducing students' MA levels.

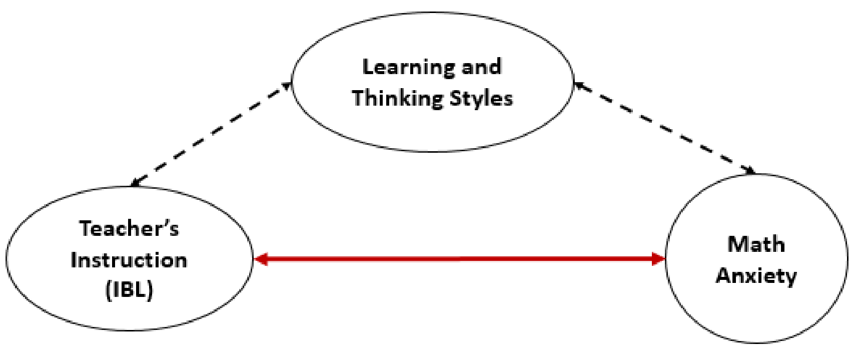


Figure 24. Results of research question 2

Note. The bold line indicates that there was a significant difference between teachers' instruction and math anxiety. Dotted lines show that there was no relationship between learning and thinking styles and MA or between teacher's instruction and learning and thinking styles concerning MA.

Research question 3. What aspects of instructional approaches (LCM and IBL) do students with different learning and thinking styles report as being related to mathematics anxiety? A total of 28 participants' written questionnaires revealed their feelings of MA and reaction to instructional styles with the four different themes: 1) factor of MA, 2) instructor's teaching styles in reducing MA, 3) decreasing their MA, and 4) preferred teaching style with MA.

Theme 1: Factors of Mathematics Anxiety. Twenty-eight students in LCM and IBL classes were asked, via questionnaires, about the causes of their MA. Participants mentioned six main different factors in their answers: low self-efficacy (1Ta), mathematical difficulties (1Tb), pressure of final exam (1Tc), teaching styles (1Td), learning styles (1Te), and lack of technology skills (1Tf) in both LCM and IBL. In both groups, mathematical difficulties (1Tb) was the main reason (37% in LCM and 25% in IBL) that they had MA. In LCM, the pressure of final exams (1Tc) was the next reason (19%) for MA. Then, teaching styles (1Td) (13%) and learning styles (1Te) (12%) were the following factors that affected anxiety and understanding in a classroom. In IBL, the pressure of final exams (1Tc) and lack of technology skills (1Tf) were the other main reasons (25%) that they had MA, then in individual learning styles (1Te) was the following factor (17%) that they had MA (Figure 25)

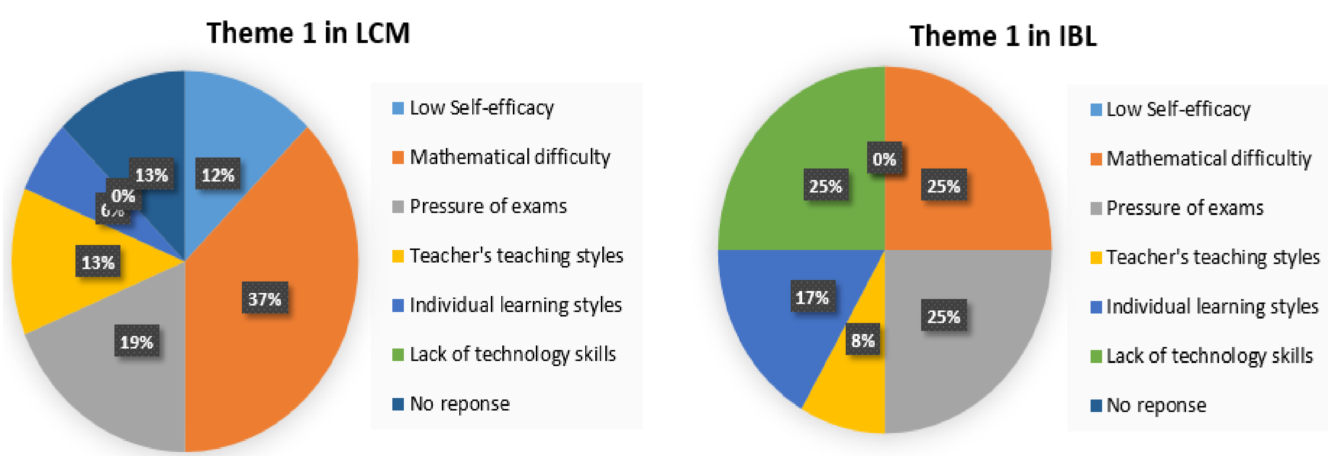


Figure 25. Factors of Mathematics Anxiety in LCM and IBL (Theme 1)

Note: mathematics difficulties (1Tb) was the predominant reasons of MA in both LCM and IBL

The findings from the written questionnaires under theme 1 suggested that the sample participants had developed their MA through personal experience and the teacher's instruction, which is consistent with the findings from previous studies (Brady & Bowd, 2005; Tobia, 1998). These results also showed that the participants in both groups had similar thoughts regarding the factors of MA.

Theme 2: Instructor's teaching styles in reducing students' MA. The participants' responses in each LCM and IBL were different in reducing their MA due to the different teaching approaches. The participants' responses (n = 16) in LCM reflected that instructor's feedback, comment, or positive influence (2a), the instructor's explanations (2b), and instructor's aid (2c) were attributed to reducing their MA. About 44 % of the sample participants in LCM indicated that instructor's explanation (2b) during the lecture was most helpful to reduce their MA. On the other hand, the participants' responses (n = 12) in IBL reflected that instructors' feedback (2d), group work (2e), and instructor's aid (2f) attributed in reducing their MA. About 42 % of the sample participants in IBL stated that group work (2e) was the main teaching style in reducing their MA. (Figure 26). These findings suggest that even though the MA levels of those participants were not significantly reduced, they felt that the way they learned became their preferred learning teaching in reducing their MA.

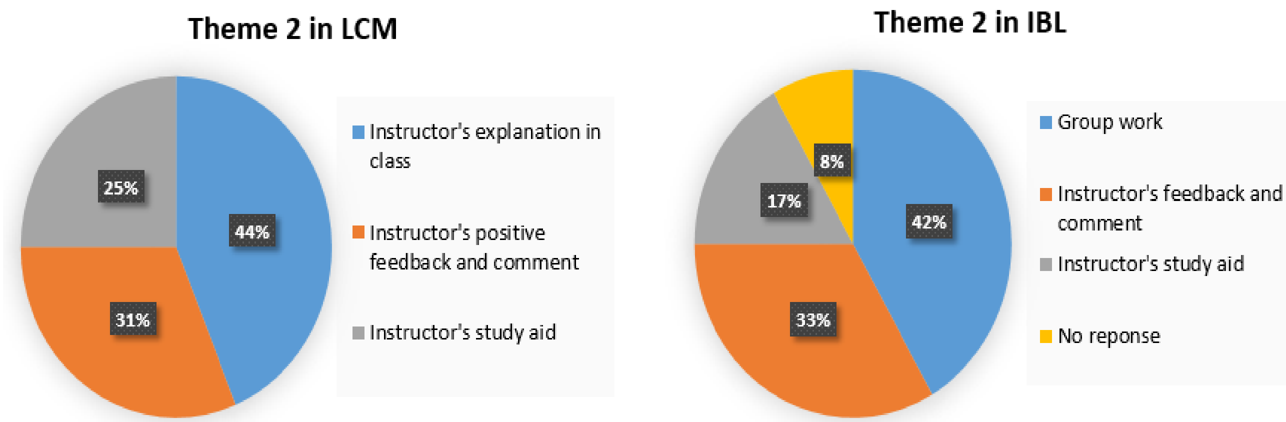


Figure 26. Instructor's teaching styles in reducing students' MA in LCM and IBL (Theme 2)

Note: in LCM, instructors' explanation (2b) was the most factor of teaching styles (44%) to reduce MA. On the other hand, in IBL, group work (2e) was the most factor of teaching styles (42%) to reduce MA.

Theme 3: Instructor's teaching styles in increasing students' MA. The participants' responses in both LCM and IBL were similar under this theme 3 with the four areas: formula and memorization (3a), teacher's deficient explanation (3b), not enough time in problem-solving (3c) or nothing (3d) (Figure 27). Most participants in both groups stated that there were no particular teaching styles that attributed to increasing their MA during the semester. Even though the teaching approaches were different in both groups and each participant' MA levels were varied among participants, most participants responded that there were no particular responses in either group concerning teaching styles that appeared to relate to increased MA in both groups. These findings suggest that the participants in each group became familiar with their understanding of the teaching approaches throughout the semester no matter whether their MA increased or decreased.

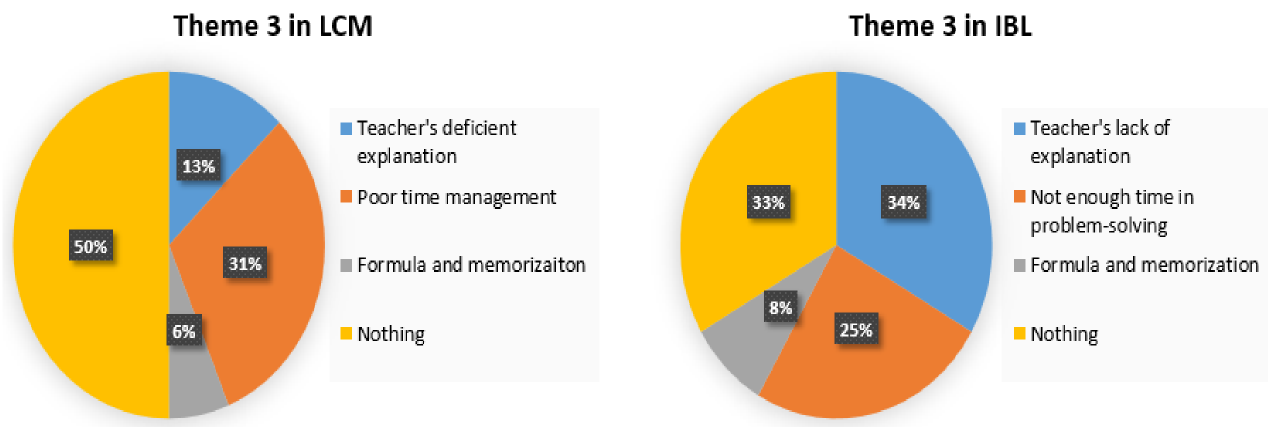


Figure 27. Instructor's teaching styles in increasing students' MA in LCM and IBL (theme 3)

Note: in both LCM and IBL, a large proportion of responses addressed that there was no evidence of teaching styles affecting their MA (50% in LCM and 33% in IBL)

Theme 4: Preferred teaching styles. The participants' responses in LCM had three areas of theme 4: detailed explanations (4a), practice with a professor (4b), and work with peers (4c) as their preferred teaching styles. About 56 % of the participants in LCM indicated that they learned best when they practiced with a professor (4b) during the class session. This result concluded that lecture approaches still became a special form of teaching and learning the content from the students' perspectives as the semester progressed. Most students became accustomed to the teacher's explanation, voice, or gesture where they focused heavily on direct instruction and practicing isolated mathematics procedures by looking at the teacher's step-by-step guide throughout the semester in LCM. On the other hand, the participants' responses in IBL suggested different areas: working with others in a group (4d), practice problems (4e), and conceptual understanding (4f) as their preferred teaching styles. About 42 % of the students in IBL indicated that they preferred to work in a group (4d) (Figure 28). This result reflected how the students had engaged in group work, collaborative learning, and discussion throughout the semester of IBL. In other words, the teachers in IBL incorporated diverse students-centered learning approaches into their classrooms where students worked together with the assistance of the teacher. These results were different from the LCM that was centered on a teacher's lecture. Some of these findings suggest that students appear to adapt to whichever teaching style they happen to be in; LCM learners report practice with the professor (e.g., worked examples in lectures) as their preferred instructional style whereas IBL learners report group work to be their preference.

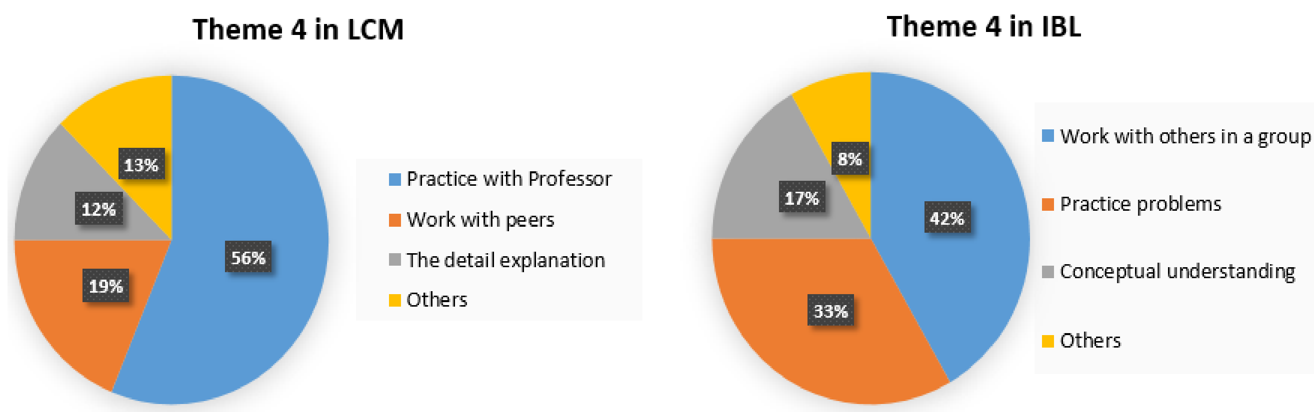


Figure 28. Preferred teaching styles in LCM and IBL (theme 4)

Note: In LCM, practice with professor (4b) was the most preferred teaching style (56%). On the other hand, in IBL, work with others in a group (4d) was the most preferred teaching styles (42%).

The sample participants (n = 28) who were interviewed in the written questionnaire might not represent all participants, but they revealed that it is important for the teachers to be aware of the possible effects of teaching style on MA. If a teacher designs a lesson plan based on student-centered instruction, it appears that student motivation increases and MA decreases. These results encourage teachers and administrators to research more inclusive teaching models where all learners are fully engaged and respected by considering all students' success in developmental mathematics courses.

Limitations

One limitation of the study is that the number of participants was not enough to generate more complex statistical analysis. A total of 61 students also dropped out of the class which could have impacted the results. Over the 15 academic weeks, 29 students in IBL dropped the classes and 32 students in LCM dropped the classes. That is, some of the non-statistical findings might attributable to not having enough statistical power to tease out differences – especially with regard to different learning styles within the two teaching styles. Also, there was a statistically significant difference between two instructional groups however, the effect size between the groups was considered small. In other words, statistically significant results might not, as a practical matter, be very significant. It is important to recognize that as sample size increases it becomes easier to find statistical significance.

In addition to this, the Cronbach's alpha tests for Gregorc's and Kolb's learning and thinking styles were low. This could mean that the measurement of these two constructs was not particularly reliable; it could be this measurement variation, in fact, and not actually the constructs themselves, that resulted in the learning and thinking styles as not being significant predictors of MA levels. In this case, given that the primary findings were in relation to the entire constructs and that the reliability of the measurements was not especially high, a case could be made that the exploration of individual learning and thinking styles, which in this study identified converger and diverger learning styles, and CS and AR thinking styles as possibly particularly benefitted by IBL instruction in terms of MA levels, warrants further attention and research.

Moreover, even though the ICC values of TA in the research question 1 was low, the p-value of linear mixed model with TA was significant between instructional approaches (LCM and

IBL). The disparity between ICC and p-value of linear mixed model showed that ICC value does not always reflect the implications of measurement error; other relevant methods could be included to investigate reliabilities to prevent misinterpretations in the future study.

Also, the researcher could not observe the classrooms all the time to make sure that the teaching styles were consistent with either IBL or LCM across through the whole 15-week period. Thus, some of the results from the study may have been attributable to individual instructor differences, and not the broad teaching styles. However, given the quantitative results appeared to mostly rule this issue out, and the qualitative observations appeared to confirm similarity across the two teaching styles, this does not appear to be a major concern. Future studies, however, might identify further ways to ensure adherence to particularly instructional styles throughout the duration of a course.

Lastly, K-flexible and G-flexible were not established in the analyses of Kolb's and Gregorc's learning styles inventory. The researcher created these new learning styles, a limitation because results could not be compared to the original Kolb's and Gregorc's learning style inventory. The addition of these two categories may have been influential on the non-significance of the two constructs as a whole with regard to MA. Additional investigation around this is warranted.

Recommendations

First, it is recommended that instructors who may not be familiar with student-centered learning approaches have the opportunity to participate in professional development to learn about diverse teaching strategies under student-centered learning pedagogy. Based on findings from this study, instructors who have a chance to learn about active learning and diverse teaching strategies will be more effective in helping students to build conceptual understanding of math strategies and to connect their knowledge to real-life problems with less anxiety. Moreover, this opportunity will permit the instructor to give stronger feedback to all students as well. With appropriate advice, students should be able to engage with activities that award them ownership with increased confidence.

In the classroom, the instructor needs to be aware of students' thoughts, feelings, and attitudes as they are related to mathematics. Thus, altering the way of talking to students about mathematical ideas, homework, or tests can encourage students to consider changing their views in a mathematics classroom. For students who need extra help, referring them to the available school resources such as the Mathematics Lab, additional materials, study groups, mathematics clubs, the instructor's office hours, counselor meetings, or mathematics workshops can encourage students to deal with their MA at the beginning of the course. This useful information can help students to increase confidence by creating regular study habits. Moreover, not only modifying an instructional approach to cater to students' individual differences, but also teachers can bring out the following behaviors and attitudes: talking about their individual process of defining, thinking and doing mathematics; convincing students to participate in the exchange of definitions, facts, ideas, concepts, applications, approaches to problem solving, and what they are thinking, as it relates to the current class session; accepting both their correct responses and incorrect responses equally; and encouraging students to correct the instructor while he or she is performing on stage. Also, instructors can help students to be comfortable with their mistakes, and give enough time to think what they know, write what they think, and share with peers collaboratively.

Additionally, no matter what students preferred learning or thinking styles, it is important for teacher not only to utilize diverse instructional approaches such as active learning, group work, and inclusive teaching strategies but also to value effort, persistence, and hard work to all students in math. For students, knowing their studying strategies and adapting teachers' instructions will be more important to their learning processes than knowledge of students' individual learning or thinking styles. Regardless of learning or thinking styles, students can learn more deeply through their studying strategies, studying habits, effort, time, and persistence. Students can achieve their goal through studying time and their own studying tactics such as asking for help, engaging with others, group communication, organizing thoughts, taking note from class, summoning their prior knowledge, proactive thinking, reflecting on assignment, and reviewing lessons. By recognizing their studying strategies and instructional method, students will be able to modify the way that they study in order to improve their academic capacity with less MA levels.

Lastly, since there was no evidence to build a relationship between learning and thinking styles of learners and their MA in this study, the Kolb's or Gregorc's instrument can be revised to have a better understanding of learning and thinking styles for the future study. Future research can be extended to other college mathematics courses in order to investigate whether different teaching approaches such as technology integration instruction, game-based instruction, or other active learning strategies impact students' MA levels. Moreover, since a number of students dropped the course over the semester, future study can consider the MA levels of diverse students who are low income family students, English language learners, first-college generation students or recent immigrants at an urban community college to see whether there is any correlation between their backgrounds and MA levels. The future study should focus on how these students' personal and societal backgrounds are associated with their unpreparedness for college-levels work or dropout rates in mathematics. Also, their behaviors, attitudes, growth mind set toward learning mathematics, studying strategies, effort, and hard work can be studied to find any correlation with reducing students' MA levels or increasing their confidence in mathematics. Future longitudinal studies will also provide other insights into the impact of teaching instruction and MA.

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APPENDIX A:

IRB Approval Letter

Expedited Review Approved by Chair - Waiver Documentation of IC - IRB ID: 18-143

Curt Naser <noreply@axiommentor.com> Thu, Dec 14, 2017 at 6:25 PM
Reply-To: Curt Naser <curtn@axiomeducation.com>
To: sb3412@tc.columbia.edu

TEACHERS COLLEGE
COLUMBIA UNIVERSITY

Teachers College IRB *Expedited Approval Notification*

To: Sunyoung Ban
From: Amy Camilleri
Subject: IRB Approval: 18-143 Protocol
Date: 12/14/2017

Please be informed that as of the date of this letter, the Institutional Review Board for the Protection of Human Subjects at Teachers College, Columbia University has given full approval to your study, entitled "*The Influence of Teaching Instruction and Learning Styles on Mathematics Anxiety in Remedial Mathematics Courses* ," under **Expedited Review** (Category **(7) Research on individual or group characteristics or behavior**).

The approval is effective until **12/13/2018**.

The IRB Committee must be contacted if there are any changes to the protocol during this period. **Please note:** If you are planning to continue your study, a Continuing Review report must be submitted to either close the protocol or request permission to continue for another year. Please submit your report by **11/29/2018** so that the IRB has time to review and approve your report if you wish to continue your study. The IRB number assigned to your protocol is **18-143**. Feel free to contact the IRB Office (212-678-4105 or IRB@tc.edu) if you have any questions.

Your request for a waiver of documentation of informed consent has been granted. You may collect consent electronically rather than obtain written signatures on paper.

You can retrieve a PDF copy of this approval letter from the Mentor site.

Best wishes for your research work.

APPENDIX B:

Email to Coordinate with Instructor

[Sample Email to find the instructors who cooperated with me to conduct the pre- and post-survey]

Dear Prof. xxx

Hope your New Year is off to a good start.

As I mentioned in the last semester, I'm looking for faculty who would like to participate in my research. In my research, I want to measure students' math anxiety and their learning styles. In order to measure them, students will do online survey beginning of the semester (15-20 minutes) and end of the semester (15-30 minutes) by using their cell phone during the class. I would like to collect this data from your MAT 56 class in spring 2018.

Coordinated Survey Instruction in MAT 56 spring 2018:

- 1st Visit (10 mints): The researcher or co-ordinates professor will collect your students' email address
- 2nd Visit (20 mints): The pre-survey will be administrated to your students during the class to measure math anxiety level and learning styles (Kolb's and Gregorc's)
- 3rd Visit (20 mints): The post-survey will be administrated to your students during the class to measure math anxiety levels.

Please let me know if you can coordinate with me to conduct these surveys. If you agree, I will visit your class on Jan 30 to collect students' email.

Thank you for your cooperation!

Best,
Sun Young Ban

APPENDIX C:

ABBREVIATED MATHEMATICS ANXIETY RATING SCALE (A-MARS) QUESTIONNAIRE

Below are 11 statements that you may agree or disagree with using the 1-5 scale below, where "Not at all", "A little", "A fair amount", "Much", or "Very much". Negative statements will be weighted from 1 to 5, and positive statements are reversed.

1. Studying for a math test (A-MARS1)
   ☐Not at all, ☐A little ☐A fair amount ☐Much ☐Very much

2. Taking math section of the college entrance exam (A-MARS2)
   ☐Not at all, ☐A little ☐A fair amount ☐Much ☐Very much

3. Taking math exam (quiz) in a math course (A-MARS3)
   ☐Not at all, ☐A little ☐A fair amount ☐Much ☐Very much

4. Taking an exam (final) in a math course (A-MARS4)
   ☐Not at all, ☐A little ☐A fair amount ☐Much ☐Very much

5. Picking up math textbook to begin working on a homework assignment (A-MARS5)
   ☐Not at all, ☐A little ☐A fair amount ☐Much ☐Very much

6. Being given homework assignments of many difficult problems that are due the next class meeting (A-MARS6)
   ☐Not at all, ☐A little ☐A fair amount ☐Much ☐Very much

7. Thinking about an upcoming math test 1 week before (A-MARS7)
   ☐Not at all, ☐A little ☐A fair amount ☐Much ☐Very much

8. Thinking about an upcoming math test 1 day before (A-MARS8)
   ☐Not at all, ☐A little ☐A fair amount ☐Much ☐Very much

9. Thinking about an upcoming math test 1 hour before (A-MARS9)
   ☐Not at all, ☐A little ☐A fair amount ☐Much ☐Very much

10. Realizing you have to take a certain number of math classes to fulfill requirements (A-MARS10)
    ☐Not at all, ☐A little ☐A fair amount ☐Much ☐Very much

11. Picking up math textbook to begin a difficult (A-MARS11)

☐Not at all, ☐A little ☐A fair amount ☐Much ☐Very much

12. Receiving your final math grade in the mail (A-MARS12)
☐Not at all, ☐A little ☐A fair amount ☐Much ☐Very much

13. Opening a math or stat book and seeing a page full of problems (A-MARS13)
☐Not at all, ☐A little ☐A fair amount ☐Much ☐Very much

14. Getting ready to study for a math test (A-MARS14)
☐Not at all, ☐A little ☐A fair amount ☐Much ☐Very much

15. Being given a “pop” quiz in a math class (A-MARS15)
☐Not at all, ☐A little ☐A fair amount ☐Much ☐Very much

16. Reading a cash register receipt after your purchase (A-MARS16)
☐Not at all, ☐A little ☐A fair amount ☐Much ☐Very much

17. Being given a set of numerical problems involving addition to solve on paper (A-MARS17)
☐Not at all, ☐A little ☐A fair amount ☐Much ☐Very much

18. Being given a set of subtraction problems to solve (A-MARS18)
☐Not at all, ☐A little ☐A fair amount ☐Much ☐Very much

19. Being given a set of multiplication problems to solve (A-MARS19)
☐Not at all, ☐A little ☐A fair amount ☐Much ☐Very much

20. Being given a set of division problems to solve (A-MARS 20)
☐Not at all, ☐A little ☐A fair amount ☐Much ☐Very much

21. Buying a math textbook (A-MARS 21)
☐Not at all, ☐A little ☐A fair amount ☐Much ☐Very much

22. Watching a teacher work on an algebraic equation on the blackboard (A-MARS 22)
☐Not at all, ☐A little ☐A fair amount ☐Much ☐Very much

23. Signing up for a math course (A-MARS 23)
☐Not at all, ☐A little ☐A fair amount ☐Much ☐Very much

24. Listening to another student explain a math formula (A-MARS 24)
☐Not at all, ☐A little ☐A fair amount ☐Much ☐Very much

25. Walking into a math class (A-MARS 25)
☐Not at all, ☐A little ☐A fair amount ☐Much ☐Very much

APPENDIX D:

Kolb's Learning Style Inventory (1984)

Rank order each set of four works (going across) in the 10 items listed below. Assign a 4 to the word which best characterizes your learning style, a 3 to the next best, a 2 to the next, and a 1 to the least characteristic word. Assign a different number to each of the four words. Do not make ties.

1. _____ involved _____ tentative _____ discriminating _____ practical
2. _____ receptive _____ impartial _____ analytical _____ relevant
3. _____ feeling _____ watching _____ thinking _____ doing
4. _____ accepting _____ aware _____ evaluating _____ risk-taker
5. _____ intuitive _____ questioning _____ logical _____ productive
6. _____ concrete _____ observing _____ abstract _____ active
7. _____ present-oriented _____ reflecting _____ future-oriented _____ practical
8. _____ open to new experience _____ perceptive _____ intelligent _____ competent
9. _____ experience _____ observation _____ conceptualization _____ experimentation
10. _____ intense _____ reserve _____ rational _____ responsible

For scoring only

_____ (CE) _____ (RO) _____ (AC) _____ (AE)

APPENDIX E:

Gregorc's Thinking Style (1984)

Read each set of words and mark the two that best describe.

1.	a.	imaginative	9.	a.	reader
	b.	investigative		b.	people person
	c.	realistic		c.	problem solver
	d.	analytical		d.	planner
2.	a.	organised	10.	a.	memorise
	b.	adaptable		b.	associate
	c.	critical		c.	think-through
	d.	inquisitive		d	originate
3.	a.	debating	11.	a.	changer
	b.	getting to the point		b.	judger
	c.	creating		c.	spontaneous
	d.	relating		d.	wants direction
4.	a.	personal	12.	a.	communicating
	b.	practical		b.	discovering
	c.	academic		c.	cautious
	d.	adventurous		d.	reasoning
5.	a.	precise	13.	a.	challenging
	b.	flexible		b.	practising
	c.	systematic		c.	caring
	d.	inventive		d.	examining
6.	a.	sharing	14.	a.	completing work
	b.	orderly		b.	seeing possibilities
	c.	sensible		c.	gaining ideas
	d.	independent		d.	interpreting
7.	a.	competitive	15.	a.	doing
	b.	perfectionist		b.	feeling
	c.	cooperative		c.	thinking
	d.	logical		d.	experimenting
8.	a.	intellectual			
	b.	sensitive			
	c.	hardworking			
	d.	risk-taking			

APPENDIX F:

Written Questionnaire

The following questions were conducted for the written questions in both LCM and IBL at the end of the semester:

Please write more than 3 sentences and explain your thoughts and opinions.

1. Did you experience mathematics anxiety during the 15 weeks of the semester? If so, please explain what do you think that the factor of your feelings of mathematics anxiety?
2. Do you think that this math course helped reduced your feelings of mathematics anxiety? Please explain
3. Please explain anything about instructor's teaching style that helped reduce your feeling of mathematics anxiety.
4. Please explain anything about instructor's teaching style that helped increase your feeling of mathematics anxiety.
5. How do you learn mathematics best? (What kinds of teaching style do you prefer? Activities? Practice problems?) Please explain.
6. Can you describe your struggle that you have in learning mathematics?
7. Do you believe that those struggles are related to your particular learning styles? Please explain.
8. Do you share your struggles when learning mathematics with others? Please explain.

APPENDIX G:

Written Questionnaire Codes

Theme 1. Factors Mathematics Anxiety

1Ta. Low self-efficacy
1Tb. Mathematical difficulty (homework, terminology, formula, new learning)
1Tc. Pressure of Exams
1Td. Teachers' teaching styles
1Te. Individual learning styles
1Tf. Web-based Instruction (WeBWork)

Theme 2. Instructor's Teaching Style to reduce Students' MA
2Ta. The components of teaching style

- Teachers' Feedback and comments, checking for understanding
- Clear Explanation
- Small group, activity collaboration, discussion
- Review Session Redoing mathematics problem
- Visually how to solve the problem

Theme 3. Instructor's Teaching Style to Increase Students' MA
3Ta. The components of teaching style

- Teachers' deficient explanation
- Poor time management
- some concepts are not taught in class (No class materials/activity)
- Formula and memorization

Theme 4. The relationship between struggle with mathematics learning and Individual Learning Styles

4Ta. The Components of Students' struggle with mathematics
- Memorizing formula
- Teaching style
- Lack of understanding
- Word problem
- Learning new concept
- Using technology such as WeBWork

4Tb. The Component of Preferred learning styles with mathematics
- Prefer step-by-step
- Prefer to practice many time
- Prefer to hands on activity

APPENDIX H:

Assumption of Regression Model

Coefficients

Model		Unstandardized Coefficients		Standardized Coefficients	t	Sig.	Collinearity Statistics	
		B	Std. Error	Beta			Tolerance	VIF
1	(Constant)	1.047	.170		6.157	.000		
	Pre-AMARS	.673	.058	.644	11.683	.000	.999	1.001
	TCM	-.340	.102	-.184	-3.331	.001	.999	1.001

a. Dependent Variable: Post-AMARS

APPENDIX I:

Calculate Intraclass Correlation Coefficient (ICC) with RQ 1

1. Post-AMARS= $b_0 + b_1$ * pre-AMARS + b_2 * (IBL) + b_{i*} (1 | Instructor) + e

Random Effect

Label	Intercept	Residual
StdDev	0.1580	0.7086

Variance of Intercept = .1580^2 = 0.0249
Variance of residual = .7086^2 = 0.5021
ICC = 0.0249 / (0.0249 + 0.5021) = **0.05**

Note. Approximately, ICC is 0.05 that indicates similarity among five LCM classes and among the other five IBL classes

2. Post-TA= $b_0 + b_1$ * pre-TA + b_2 * (IBL) + b_{i*} (1 | Instructor) + e

Random Effect

Label	Intercept	Residual
StdDev	0.1169	0.7471

Variance of Intercept = .1169^2 = 0.0136
Variance of residual = .7471^2 = 0.5581
ICC = 0.0136 / (0.0136 + 0.5581) = 0.024

Note. A low ICC (0.02) indicates there is no similarity among five LCM classes and among the other five IBL classes

3. Post-NA= $b_0 + b_1$ * pre-NA + b_2 * (IBL) + b_{i*} (1 | Instructor) + e

Random Effect

Label	Intercept	Residual
StdDev	0.1791	0.9368

Variance of Intercept = .1791^2 = 0.0321
Variance of residual = .9368^2 = 0.8776
ICC = 0.0321 / (0.0321+ 0.8776) = 0.04

Note. A low ICC (0.04) indicates there is no similarity among five LCM classes and among the other five IBL classes

4. Post-MCA= $b_0 + b_1$ * pre-MCA + b_2 * (IBL) + b_{i*} (1 | Instructor) + e

Random Effect

Label	Intercept	Residual
StdDev	0.1960	0.8718

Variance of Intercept = .1960^2 = 0.0384
Variance of residual = .8718^2 = 0.7600
ICC = 0.0384 / (0.0384+ 0.7600) **= 0.05**

Note. Approximately, ICC is 0.05 that indicates similarity among five LCM classes and among the other five IBL classes

APPENDIX J:

Calculate Intraclass Correlation Coefficient (ICC) with Kolb's learning styles

1. Post-AMARS= b_0 + b_1 * pre-AMARS + b_2 * (IBL) + b_3 * (Kolb's Learning Styles) + b_i * (1 | Instructor) + e

Random Effect

Label	Intercept	Residual
StdDev	0.162	0.712

Variance of Intercept = .1620^2 = 0.0262
Variance of residual = .712^2 = 0.5068
ICC = 0.0262 / (0.0262 + 0.5068) = **0.049**

Note. Approximately, ICC is 0.05 that indicates similarity among five LCM classes and among the other five IBL classes

2. Post-TA= b_0 + b_1 * pre-TA + b_2 * (IBL) + b_3 * (Kolb's Learning Styles) + b_i * (1 | Instructor) + e

Random Effect

Label	Intercept	Residual
StdDev	0.1178	0.7521

Variance of Intercept = .1178^2 = 0.01387
Variance of residual = .7521^2 = 0.5656
ICC = 0.0138 / (0.0138 + 0.5656) = 0.0238

Note. A low ICC (0.02) indicates there is no similarity among five LCM classes and among the other five IBL classes

3. Post-NA= b_0 + b_1 * pre-NA + b_2 * (IBL) + b_3 * (Kolb's Learning Styles) + b_i * (1 | Instructor) + e

Random Effect

Label	Intercept	Residual
StdDev	0.1888	0.9398

Variance of Intercept = .1888^2 = 0.0356
Variance of residual = .9398^2 = 0.8832
ICC = 0.0356 / (0.0356 + 0.8832) = 0.0403

Note. A low ICC (0.04) indicates there is no similarity among five LCM classes and among the other five IBL classes

4. Post-MCA= b_0 + b_1 * pre-MCA + b_2 * (IBL) + b_3 * (Kolb's Learning Styles) + b_i * (1 | Instructor) + e

Random Effect

Label	Intercept	Residual
StdDev	0.1980	0.8796

Variance of Intercept = .1980 ^2 = 0.0392
Variance of residual = .8796^2 = 0.7736
ICC = 0.0392 / (0.0392 + 0.7736) = **0.048**

Note. Approximately, ICC is 0.05 that indicates similarity among five LCM classes and among the other five IBL classes

APPENDIX K:

Estimates of Fixed Effects for the TA, NA, and MCA with Kolb's Learning Styles

Estimates of Fixed Effects for the TA with Kolb's learning styles (n =185)

Variable	Variable	Variable	Variable	Variable
Intercept	1.3314	0.2418	5.5056	<.000
Pre-TA	0.6587	0.0560	11.7558	**<.0000**
IBL	-0.3524	0.1356	-2.5989	**0.0317**
Diverger	-0.1584	0.2047	-0.7736	0.4408
Assimilator	-0.1269	0.2219	-0.5720	0.5680
Converger	-0.0157	0.2100	-0.749	0.9403
Accommodator	0.0016	0.2093	0.007	0.9938

Note. There is no significant difference in TA among students with different learning styles except Pre-TA, and IBL in a linear mixed model.

Estimates of Fixed Effects for the NA with Kolb's learning styles (n=185)

Variable	Coefficient	Standard. Error	t-value	Pr > |t|
Intercept	1.0459	0.2777	3.7663	<.0002
Pre-NA	0.5614	0.0705	7.9556	**<.0000**
IBL	-0.0229	0.1854	-0.1239	0.9045
Diverger	-0.3691	0.2551	-1.4470	0.1497
Assimilator	-.2873	0.2774	-1.0356	0.3019
Converger	-0.2180	0.2618	-0.8325	0.4063
Accommodator	-0.1604	0.2620	-0.6124	0.5411

Note. There is no significant difference in NA among students with different learning styles except Pre-TA in a linear mixed model.

Estimates of Fixed Effects for the MCA with Kolb's learning styles (n=185)

Variable	Coefficient	Standard. Error	t-value	Pr > |t|
Intercept	1.1894	0.2568	4.6309	<.0000
Pre-MCA	0.5997	0.0609	9.8424	**<.0000**
IBL	-0.3510	0.1824	-1.9238	0.0906
Diverger	-0.1746	0.2389	-0.7310	0.4657
Assimilator	-0.1556	0.2598	-0.59916	0.5499
Converger	-0.0662	0.2457	-0.2697	0.7877
Accommodator	-0.0846	0.2471	-0.3425	0.7323

Note. There is no significant difference in MCA among students with different learning styles except Pre-TA in a linear mixed model.

APPENDIX L:

Selected Kolb's Learning Styles (Diverger and Converger learners)

Post-AMARS

Label	Parameter Estimate	Standard Error	t-value	Pr > |t|
Intercept	1.0395	0.3570	2.91	0.0054
Pre-AMARS	0.6633	0.1234	5.37	0.0001
IBL	-0.3932	0.1951	-2.02	**0.0495**

Post-TA = $b_0 + b_1$*Pre-TA + b_2*IBL; with only diverger

Note. Given the students with only diveger learning styles (n =51), the post-AMARS decreased by 0.3932 (pvalue = 0.0495)

Post-TA

Label	Parameter Estimate	Standard Error	t-value	Pr > |t|
Intercept	1.4694	0.3900	3.77	0.0005
Pre-TA	0.5847	0.1168	5.00	0.0001
IBL	-0.4617	0.2233	-2.07	**0.0441**

Post-TA = $b_0 + b_1$*Pre-TA + b_2*IBL; with only diverger

Note. Given the students with only diveger learning styles (n =51), the post-TA decreased by 0.4617 (p-value = 0.0441)

Post-TA

Label	Parameter Estimate	Standard Error	t-value	Pr > |t|
Intercept	0.9467	0.3101	3.05	0.0043
Pre-TA	0.7958	0.0895	8.89	0.0001
IBL	-0.5798	0.1985	-2.92	**0.00061**

Post-TA = $b_0 + b_1$*Pre-TA + b_2*IBL; with only converger

Note. Given the students with only converger learning styles (n =38), the post-TA decreased by 0.5798 (p-value = 0.000061)

APPENDIX M:

Calculate Intraclass Correlation Coefficient (ICC) with Gregorc's thinking styles

1. Post-AMARS= b_0 + b_1*pre-AMARS + b_2*(IBL) + b_3*(Gregorc's thinking Styles) + bi*1 | Instructor) + e

Random Effect

Label	Intercept	Residual
StdDev	0.1611	0.7093

Variance of Intercept = .1611^2 = 0.0259
Variance of residual = .7093^2 = 0.5031
ICC = 0.0259 / (0.0259 + 0.5031) = **0.0489**

Note. Approximately, ICC is 0.05 that indicates similarity among five LCM classes and among the other five IBL classes

2. Post-TA= b_0 + b_1 * pre-TA + b_2 * (IBL) + b_3 * (Gregorc's thinking Styles) + b_i * (1 | Instructor) + e

Random Effect

Label	Intercept	Residual
StdDev	0.1356	0.7139

Variance of Intercept = .1356^2 = 0.0183
Variance of residual = .7139^2 = 0.5097
ICC = 0.0183 / (0.0183 + 0.5097) = 0.0347

Note. A low ICC (0.03) indicates there is no similarity among five LCM classes and among the other five IBL classes

3. Post-NA= b_0 + b_1 * pre-NA + b_2 * (IBL) + b_3 * (Gregorc's thinking Styles) + b_i * (1 | Instructor) + e

Random Effect

Label	Intercept	Residual
StdDev	0.1643	0.9466

Variance of Intercept = .1643^2 = 0.0270
Variance of residual = .9466^2 = 0.8962
ICC = 0.0270 / (0.0270 + 0.8962) = 0.029

Note. A low ICC (0.03) indicates there is no similarity among five LCM classes and among the other five IBL classes

4. Post-MCA= b_0 + b_1 * pre-MCA + b_2 * (IBL) + b_3 * (Gregorc's thinking Styles) + b_i * (1 | Instructor) + e

Random Effect

Label	Intercept	Residual
StdDev	0.1857	0.8670

Variance of Intercept = .1857^2 = 0.0345
Variance of residual = .8670^2 = 0.7516
ICC = 0.0345 / (0.0345 + 0.7516) = 0.0438

Note. A low ICC (0.04) indicates there is no similarity among five LCM classes and among the other five IBL classes

APPENDIX N:

Estimates of Fixed Effects for the TA, and NA with Gregorc's Thinking Styles

Estimates of Fixed Effects for the TA with Gregorc's thinking styles (n = 185)

Variable	Coefficient	Standard. Error	t-value	Pr > |t|
Intercept	1.2501	0.2275	5.4943	<.0000
Pre-TA	0.6351	0.0570	11.1405	**<.0000**
IBL	-0.3811	0.1394	-2.7327	**0.0257**
AR	0.1987	0.1641	1.2105	0.2277
AS	0.3051	0.2025	1.5064	0.1338
CR	-0.0661	0.1958	-0.3376	0.7360
CS	0.0451	0.1728	0.2611	0.7943

Note. There is no significant difference in TA among students with different learning styles except Pre-TA, and IBL in a linear mixed model.

Estimates of Fixed Effects for the NA with Gregorc's thinking styles (n = 185)

Variable	Coefficient	Standard. Error	t-value	Pr > |t|
Intercept	0.7997	0.2379	3.3618	<.0000
Pre-NA	0.5645	0.0720	7.8307	**<.0000**
IBL	-0.0586	0.1746	-0.3357	0.7457
AR	0.0697	0.2083	0.3347	0.7382
AS	-0.1207	0.2585	-0.4670	0.6411
CR	-0.0067	0.2462	-0.0273	0.9782
CS	0.0765	0.2225	0.3439	0.7313

Note. There is no significant difference in NA among students with different learning styles except Pre-NA in a linear mixed model.

APPENDIX O:

Selected Gregorc's Thinking Styles (AR and CS learners)

Post-AMARS

Label	Parameter Estimate	Standard Error	t-value	Pr > |t|
Intercept	0.8957	0.3206	2.79	0.0072
Pre-AMARS	0.7733	0.1126	6.86	0.0001
IBL	-0.3665	0.1782	-2.06	**0.0447**

Post-AMARS = $b_0 + b_1$*Pre-AMARS + b_2*IBL; with only AR
Note. Given the students with only AR learning styles (n =56), the post-AMARS decreased by 0.3665 (p-value = 0.0447)

Post-TA

Label	Parameter Estimate	Standard Error	t-value	Pr > |t|
Intercept	1.0676	0.3631	2.94	0.0049
Pre-TA	0.7609	0.1085	7.01	0.0001
IBL	-0.4201	0.1943	-2.16	**0.0352**

Post-TA = $b_0 + b_1$*Pre-TA + b_2*IBL; with only AR
Note. Given the students with only AR learning styles (n =56), the post-AMARS decreased by 0.4201 (p-value = 0.0352)

Post-MCA

Label	Parameter Estimate	Standard Error	t-value	Pr > |t|
Intercept	1.5782	0.4610	3.42	0.0014
Pre-MCA	0.5339	0.1425	3.75	0.0006
IBL	-0.8356	0.3159	-2.64	**0.0115**

Post-MCA = $b_0 + b_1$*Pre-MCA + b_2*IBL; with only CS
Note. Given the students with only CS learning styles (n =44), the post-AMARS decreased by 0.8356 (p-value = 0.0115)

APPENDIX P:

Informed Consent Form

Protocol Title: The influence of Teaching Instruction and Learning Styles on Mathematics Anxiety in Remedial Mathematics Courses
Principal Investigator: Sun Young Ban, sb3412@tc.columbia.edu Teachers College

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INTRODUCTION
You are being invited to participate in this research study called "The influence of Teaching Instruction and Learning Styles on Mathematics Anxiety in Remedial Mathematics Courses." You may qualify to take part in this research study because you are over 18 years old, and you are taking one of remedial mathematics courses. Approximately one-hundred people will participate in this study and it will take about total 50 minutes of your time to complete two online surveys in the beginning and at the end of semester.

WHY IS THIS STUDY BEING DONE? The relationship between mathematics anxiety (MA) and learning styles has been studied extensively, but there are not many studies that show the relationship between the math anxiety and the compatibility between learning styles and teaching styles. This study is being done to determine how understanding learning styles and teaching instructions may affect mathematics anxiety.

WHAT WILL I BE ASKED TO DO IF I AGREE TO TAKE PART IN THIS STUDY?
If you decide to participate, you will be surveyed online by the principal investor. During the survey, you will be asked to answer about your education experience and your experience as a student who takes remedial mathematics course**.** After the survey is completed, the survey will be stored in password-protected folder on the Principal Investigator's password-protected computer. The survey will take about 25 minutes as a in the beginning as a pre-survey, and another 25 minutes at the end of the semester as post-survey. You will also be asked to compete a brief demographic survey. You will be given a de-identified code in order to keep your identity confidential. All of these procedures will be done by online survey in your MAT 56 class at Borough of Manhattan community college

WHAT POSSIBLE RISKS OR DISCOMFORTS CAN I EXPECT FROM TAKING PART IN THIS STUDY?
This is a minimal risk study, which means the harms or discomforts that you may experience are not greater than you would ordinarily encounter in daily life while taking routine physical or psychological examinations or tests. However, there are some risks to consider. You might feel embarrassed to discuss problems that you experienced in survey. **However, you do not have to answer any questions or divulge anything you don't want to talk about. You can stop participating in the study at any time without penalty.** You might also feel concerned that things you say might get back to your instructor. The principal investigator is taking precautions to keep your information confidential and prevent anyone from discovering or guessing your identity, such as using a de-identified code instead of your name and keeping all information on a password protected computer and locked in a file drawer.

WHAT POSSIBLE BENEFITS CAN I EXPECT FROM TAKING PART IN THIS STUDY? There is no direct benefit to you for participating in this study. Participation may benefit the field of learning mathematics to better understand which instruction will match to their learning styles and mathematics anxiety.

WILL I BE PAID FOR BEING IN THIS STUDY? If you choose to participate in this study, you will be entered into a chance to win a $20 gift card for completing each online survey distributed at the beginning and end of the semester. There is a 1/25 chance of winning the $20 gift card for each online survey. There are no costs to you for taking part in this study.

WHEN IS THE STUDY OVER? CAN I LEAVE THE STUDY BEFORE IT ENDS? The study is over when you have completed the both beginning and end of the surveys. However, you can leave the study at any time even if you haven't finished.

PROTECTION OF YOUR CONFIDENTIALITY The investigator will keep all digital materials locked in a desk drawer in a locked office. Any electronic or digital information (including online survey) will be stored on a computer that is password protected. There will be no record matching your real name with your de-identified code.

HOW WILL THE RESULTS BE USED? The results of this study will be published in journals and presented at academic conferences. Your name or any identifying information about you will not be published. This study is being conducted as part of the dissertation of the principal investigator.

WHO CAN ANSWER MY QUESTIONS ABOUT THIS STUDY?
If you have any questions about taking part in this research study, you should contact the principal investigator, Sun Young Ban, sb3412@tc.columbia.edu Teachers College
If you have questions or concerns about your rights as a research subject, you should contact the Institutional Review Board (IRB) (the human research ethics committee) at 212-678-4105 or email IRB@tc.edu. Or you can write to the IRB at Teachers College, Columbia University, 525 W. 120th Street, New York, NY 1002. The IRB is the committee that oversees human research protection for Teachers College, Columbia University.

PARTICIPANT'S RIGHTS

- I have read and discussed the informed consent with the researcher. I have had ample opportunity to ask questions about the purposes, procedures, risks and benefits regarding this research study.
- I understand that my participation is voluntary. I may refuse to participate or withdraw participation at any time without penalty to future medical care; employment; student status or grades; services that I would otherwise receive.

- The researcher may withdraw me from the research at his or her professional discretion.
- If, during the course of the study, significant new information that has been developed becomes available which may relate to my willingness to continue my participation, the investigator will provide this information to me.
- Any information derived from the research study that personally identifies me will not be voluntarily released or disclosed without my separate consent, except as specifically required by law.
- I should receive a copy of the Informed Consent document.

Click "I agree." If you agree to participate in this study.

_____I agree to participate in this study,

_____I disagree to participate in this study

NAME: ______________________ Signature: _____________________________

Click "Next" to continue