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The Effect of Quantum Learning Model on Attitude, Anxiety, and Achievement of Middle School Students Towards Mathematics[1]

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Abstract

We conducted this research to investigate the impact of the Quantum Learning Model (QLM) on the academic achievement, attitudes toward mathematics, and anxiety levels of seventh-grade middle school students. A total of fifty-six 7th-grade students participated in the research. The research used a quasi-experimental model with a pretest-posttest control group. The experimental group used QLM during the research process, while the control group used the current learning approach. We conducted the research for 28 lesson hours. We collected data using attitude, anxiety scale, and academic achievement tests. We applied tests to both groups before and after the experimental procedure. We used independent-samples-T-tests and paired-samples-T tests in the analyses. We also evaluated the journals of students and the researcher. Accordingly, QLM had a positive effect on middle school students' academic achievement in mathematics. The posttest mean scores of attitudes decreased significantly in the control group. The experimental group experienced a decrease in post-test mean scores of anxiety, which was not statistically significant, whereas the control group experienced a statistically significant increase in post-test scores. Students and teachers have expressed positive opinions about the use of note-taking and mind maps, which enhance the durability of learning, the establishment of a classroom environment and atmosphere conducive to QLM, and the implementation of celebration activities.

Keywords: Quantum learning model, achievement, attitude, anxiety, mathematics.

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Introduction

Learning takes place permanently and meaningfully through the effective use of the current process in accordance with theories, models, strategies, techniques, styles, and teaching tools. Learning and teaching activities require multiple contexts. Teachers should adjust this versatile context in teaching to the individual psychosocial development, learning styles, and characteristics of the students. In other words, they should apply the appropriate principles of the theories following the learning-teaching conditions and variables (Duman, 2004).

Today's teaching methods and techniques widely incorporate student-centered approaches. Quantum learning, rooted in the principles of metacognition and permanent learning, empowers individuals to actualize their potential by facilitating the development of their personalized learning framework. Our education system's goal is to raise such individuals. Individuals with this characteristic can create something new that is beneficial to society (Ministry of National Education, 2018). Quantum learning will also make the person self-confident, as it enables him to learn on his own. In this way, people will look at events without prejudice and try to solve problems (DePorter & Hernacki, 1992). The bias that exists towards mathematics is one of the critical problems in our system of education. This research aims to demonstrate that mathematics is an approachable and achievable subject and to foster positive attitudes towards mathematics. Therefore, this research aims to experimentally illustrate this concept, considering the principles of QLM, and contribute to the expanding body of research on this subject.

Quantum Learning

Quantum learning's foundations are based on quantum physics. Quantum physics is a sub-branch of physics that investigates what particles exist in the material entities that exist around us and in the universe, what events occur there, and, in short, the laws that govern this universe, which we call the micro-universe (Erol, 2010). Quantum physics expresses the results with probabilities, not with certainty and clarity. The uncertainty relation is one of quantum theory's important discoveries. Obtaining accurate data is almost impossible. Relationships are non-linear, and there is reciprocal causality. In quantum systems, diversity, openness, complexity, mutual causality, and uncertainty reflect qualitative rather than quantitative changes. Since the quantum paradigm is holistic, it sees entities and systems as a whole (Demirel et al., 2004).

The rise of quantum theory necessitated a paradigm shift. The changing paradigm emphasizes that science is not a process of producing objective knowledge, but that the scientific process is a process based on the relativity of the world (Yıldırım & Şimşek, 2005). In the social sciences, where the Newtonian paradigm is predominant, recent advancements have rendered change unavoidable. Given the fundamental changes in the quantum paradigm, it is believed that educational programs will better explain these changes (Demirel, 2009).

The optional and probabilistic goals of a quantum-referenced education program can provide significant support to the individual in preserving differences in education, openness to innovations, creativity, and coping with the complexity of life. The content of the quantum program, which includes both proven and yet unproven information, can offer the individual opportunities to freely create his reality. In a quantum program, the educational situation emphasizes "learning" based on interaction rather than "teaching," which evokes objectivity. A quantum-based program bases its measurement approach on the principle that one cannot observe individual behavior independently of context. Thus, a measurement approach that considers the process and results together, based on the integrity of the observer (participant), method, tool, and observed, comes to the fore (Akpınar & Aydın, 2009).

Related Research

"Learning Forum" an international education company, initiated Quantum Learning to enhance academic and personal skills in "SuperCamps" (DePorter, 1992). The program's goal is to increase students' academic success by improving their characteristics through applied quantum learning methods. Vos-Groenendal conducted a doctoral study on the results that he collected from the SuperCamp program between 1983 and 1989. This study included qualitative and quantitative data on 6042 participants aged between 12 and 22. Based on the research findings, the average motivation scores of students who took part in Supercamps showed a 68% rise compared to their scores on the pre-tests, 73% in their academic achievement scores, 84% in their self-esteem measurements, and 96% in their positive attitudes towards learning. The findings illustrated quantum learning's remarkable success and suggested its widespread adoption as a model. (DePorter, 1992).

Schools providing formal education carried out experimental studies with QLM applications at different grade levels and in various disciplines in the following years. For example, Nourie (1998) determined that, in a study in which 600 high school students participated, 67% of the students who were taught QLM passed the mathematics course, although the mathematics course passing rate in regular classes was 62%. Furthermore, Nourie (1998) observed positive developments in the students' high self-confidence, memory skills, dedication to the lesson, and ability to follow their teachers' example. Similarly, Myer (2005) discovered in his study with third graders that implementing quantum learning instruction led to an improvement in both reading and mathematical skills, hence enhancing mathematics accomplishment at the primary school level.

Several studies examined the results of students who applied QLM in national standard achievement tests. In Barlas et al.'s (2002) study, QLM resulted in a significant improvement in problem-solving abilities among middle school students who fulfilled academic standards but had difficulties in the classroom. In a similar vein, Benn et al. (2003) investigated the impact of the QLM on students' performance in fundamental academic courses. Based on the research findings, the implementation of the QLM had a beneficial effect on the success of students enrolled in 18 schools throughout four states. The assessments demonstrated a statistically significant and educationally meaningful improvement in academic achievement, mathematical proficiency, reading comprehension, and writing skills among students who attended quantum learning instruction, as opposed to those who did not receive such training.

In Turkey, there are various studies investigating the effects of the QLM on success and affective characteristics. For example, Demirel et al. (2004) determined that quantum learning education positively affected the learning behavior of 5th-grade students. Similarly, in his study investigating secondary school students' attitudes towards learning, Demir (2006) concluded that it had a beneficial impact on students' self-perceptions, school, learning, and course. While students' self-confidence, motivation, and reading speed increased, their stress and anxiety decreased.

Studies using the QLM are common in our country, particularly in the field of science. As an illustration, Güllü (2010) conducted a study to examine the impact of physics instruction using the QLM on the achievement, learning interest, learning styles, and brain profiles of secondary school students. The research results showed that the QLM positively impacted secondary school students' academic successes and learning desires, but it did not affect their learning styles or brain profiles. In their study, Acat and Ay (2014) investigated the impact of science and technology education, specifically using the QLM approach, on the academic performance, attitude, and self-learning skills of primary school children. These findings demonstrate the positive impact of the QLM on academic success. It has been observed that the QLM has a positive effect on the attitude towards the science course. The evaluation of teacher and student opinions concluded that quantum learning positively impacted motivation, attitude towards the lesson, group work, active participation, effective and fast learning, and the acquisition of skills. Similarly, Yilgen (2014), Alaca (2014), and Şimşek (2016) found that students' success increased in science education organized according to quantum learning. In foreign language education as a different discipline, Hanbay (2009) found in his study that the application of the "QLM" and "learning by teaching" methods together made a positive contribution to learning German as a second foreign language.

In addition to the implementation of quantum learning to primary and secondary school students, studies have also been conducted with teacher candidates. For instance, studies (Karamustafaoglu & Karamustafaoglu, 2018; Sarıgöz et al., 2015) investigate the opinions of pre-service and in-service teachers about QLM. In a similar study, Çakır (2016) examined the perceptions of primary school mathematics teacher candidates regarding the blended learning course design supported by the quantum learning cycle. Teacher candidates have a positive consensus regarding the process and are happy to take part in activities in which they are active. A study conducted by Afacan and Gürel (2019) found that quantum learning enhances the communication abilities of pre-service science teachers. In a different study, prospective teachers did not have sufficient information about the characteristics of the QLM, but they used some of the basic features of the model in their lives without being aware of them (Sarıgöz et al., 2015).

Along with these studies, analyses were also made in which national-level studies on quantum learning were examined and evaluated together (e.g., Çağlı et al., 2020; Güler & Yazıcı, 2018; Kanadlı et al., 2015; Kazu & Kaplan, 2023). For instance, Kanadlı et al. (2015) performed a meta-analysis of quantitative studies investigating the impact of the QLM on academic performance. The study found that educational environments structured based on the QLM showed a beneficial, although slight, impact on academic achievement. Güler and Yazıcı (2018), Çağlı et al. (2020), and Kuzu and Kaplan (2023) revealed that the most examined variable in quantum learning studies is academic success. In addition, these studies appear to be based on experimental models and improve the student's academic success as well as affective characteristics such as motivation, attitude, and anxiety (Güler & Yazıcı, 2018). Çağlı et al. (2020) showed that studies were generally conducted with primary school students and concentrated on science education. As a matter of fact, Kuzu and Kaplan (2023) achieved similar results regarding the QLM; qualitative research methods suggested further investigation, considering various school levels and variables.

Quantum Learning Scheme

Le Tellier and DePorter (2002) assert that Bobbi DePorter's model is a holistic approach that integrates the most effective educational practices, fosters rich classroom learning experiences, and encourages teachers to create unique teaching models. The model's holistic nature stems from its incorporation of "brain-based learning," "accelerated learning," "neurolinguistic programming," "suggestopedia," "multiple intelligence theory," "emotional intelligence," "dual and triple brain theory," and "holistic learning." This is because it includes different theories and models, such as "learning styles (visual, auditory, and kinesthetic)" (Güllü, 2010). In the QLM, which includes many approaches and models, learners use their cognitive, affective, and psychomotor features (Bakır & Koç-Akran, 2019).

According to DePorter and Hernacki (1992), quantum learning encompasses a comprehensive set of learning methods and philosophies that have demonstrated their effectiveness in both school and business settings. The structure of quantum learning revolves around the foundations, atmosphere, design, and environment. Principles, beliefs, agreements, and guidelines form its fundamentals. Its atmosphere creates honesty, trust, and personal feelings. While defining a dynamic and interesting educational program, the environment is a structure that will increase and support learning (Ayvaz, 2007).

The elements of the QLM can be grouped into two groups: context and content. Using an orchestra analogy, we can explain these elements. The magnificence of the orchestra hall (environment), the passion of the musicians and the conductor (ambiance/atmosphere), the harmony of the instruments and their collaboration (infrastructure), and the masterful interpretation of the musical piece (pattern) create the context. The combination of all these elements determines our musical experience. The other part is content, which is as important as context. People think music is just notes on paper, but it's more. For instance, the conductor's role in facilitating the orchestra's performance, the musical abilities of each musician, and the potential of each instrument all play a significant role. When we look at it from the perspective of quantum teaching, just like in the orchestra, the teacher must act as the conductor of student learning and pay attention to the context and content arrangement (Ayvaz et al., 2007).

The quantum learning scheme consists of six interrelated stages. This process consists of the stages of enrollment, association with experiences, label, demonstration, repetition, and celebration (DePorter et al., 1999):

•The enrollment phase activates students' prior knowledge and increases their desire to conduct research (DePorter et al., 1999). At this stage, we aim to capture students' attention by providing a general introduction to the course, beginning with an opening story that stimulates their curiosity without overwhelming them with relevant information (Usta, 2006). At this stage, intriguing and attention-grabbing questions, pantomimes, skits, role-playing games, videos, and stories can be used.

•During the association stage, the brain is stimulated to explore, enabling students to learn through experiences and prior knowledge. Making associations allows you to activate the student's existing knowledge and increase their sense of curiosity. Games, simulations, role-playing, group studies, mind maps, and activities that activate prior knowledge can be performed.

•The labeling phase initiates the brain's desire to label, sort, and identify. It builds new knowledge on top of the student's prior knowledge. At this stage, educators can employ graphics, quantum note-taking, memory techniques, informative posters, analogies, and presentations.

•The demonstration phase allows the student to acquire and apply new knowledge. The student incorporates the knowledge they acquire at this stage into their learning and life experiences. The demonstration stage allows for the use of sketches, videos, games, songs, and graphic presentations.

•During the repetition phase, it strengthens the nerve connections in the brain and creates a sense of self-confidence in the student. Therefore, it is important to incorporate different activities into repetition, considering the various types of intelligence and senses. During this phase, we can implement activities that allow students to impart the knowledge they've learned to a different class, students from various age groups, a teacher, an expert, or a well-known individual, as well as reinforce their learning through group studies.

•Celebration concludes the learning process by appreciating the effort, dedication, and achievement. We can use multi-profit competitions to both entertain and enable students to enjoy the new knowledge they have gained at the end of the course (Ay, 2010).

When teaching mathematics based on the stages of the quantum learning cycle, the enrollment and association stage considers the student's existing knowledge and prepares them to absorb new concepts. Additionally, associating mathematics with daily life can help students develop positive attitudes toward mathematics. At the label stage, the introduction of new concepts necessitates the use of effective note-taking techniques, informative posters, and presentations to cement the learned concepts and ensure their permanence. Students use their self-learning skills during the demonstration phase, which supports the discovery and creation process of mathematics. In the repetition phase, students can engage in activities to cement their learning. The celebration phase helps students learn and increases their motivation. These stages may also positively affect the student's attitude towards mathematics and reduce their anxiety. Quantum learning techniques can be used to facilitate collaborative group activities across all stages.

Significance

QLM's elements highlight four basic concepts in mathematics teaching: student creation of knowledge, self-regulation skills, learning in context, and cooperative learning. We understand that by dedicating the necessary effort to these elements, other details will naturally emerge, leading to the goal of enhancing mathematical tendency through process acquisition (Altun, 2007). The QLM outlines the principles required to achieve this goal. With its quantum learning atmosphere and design principle, the QLM provides a classroom environment that will motivate and support students, develop their self-learning skills, and serve as a place where students can structure and discover knowledge. The foundations and eight keys of excellence (integrity, failure leads to success, speaking with good purpose, attention to the present moment, commitment, ownership, flexibility, and balance) support the student's self-confidence, self-development, positive thinking, and determination, encouraging student participation in the learning process and boosting their motivation to study and be creative (Demir, 2006). Indeed, the studies (Benn et al., 2003; Myer, 2005; Nourie, 1998) showed that students who received quantum learning instruction improved their academic achievement, mathematical proficiency, reading comprehension, and writing skills more than those who did not.

According to Çağlı et al. (2020), most studies focused on science education with primary school children. The findings of the studies (e.g., Acat & Ay, 2014; Alaca, 2014; Güllü, 2010; Şimşek, 2016; Yilgen, 2014) show that the QLM improves academic performance, science course attitudes, motivation, group work, active involvement, effective learning, and skill acquisition. In fact, Kuzu and Kaplan (2023) suggested further investigation in different disciplines. Thus, we endeavored to contribute to the literature by using QLM in teaching mathematics.

Several studies (e.g., Demir, 2006; Demirel et al., 2004) have examined the effects of the QLM on affective characteristics. They observed that while students' self-esteem, motivation, self-learning, and self-confidence increased, their tension and anxiety reduced. Consequently, students trained with QLM approach situations impartially and strive to find solutions. One of the significant challenges in our educational system is the prejudice against mathematics. This research aims to demonstrate that mathematics is a subject that is both understandable and achievable and to support transforming negative perceptions about mathematics into positive ones. This research holds significance as it aims to empirically prove this by examining the principles of the quantum learning approach, thereby adding to the growing body of research on this topic. Therefore, the research topic focuses on the achievement, attitude, and anxiety levels of middle school students when they are taught mathematics courses using the QLM. The research questions are:

i. Is there a significant difference between the experimental and control group students' academic achievement, attitude, and anxiety scores in mathematics?
ii. Is there a significant difference between the experimental and control group students' gain scores of academic achievement, attitude, and anxiety in mathematics?
iii. What are the opinions of the instructor and students about the QLM?

Method

The current research employs an experimental model to investigate the impact of QLM in the mathematics course on the academic achievement, attitudes, and anxiety of seventh-graders, using a pretest-posttest quasi-experimental design with a control group. The goal of the study was to find out the efficacy of the independent variables (quantum learning and the current program method) on the paired variables (academic success, attitude, and anxiety towards the mathematics course). We created an experimental and a control group. We applied QLM to the experimental group but did not intervene with the current teaching method in the control group. We administered the Academic Achievement Test (AAT), the Attitude Scale Towards Mathematics (ASTM), and the Mathematics Anxiety Scale (MAS) to both groups as pre-tests and post-tests.

Participants

The study group for this research consists of students of two 7th-grade classes (7/C and 7/D) attending a public middle school. Variable control is the most important aspect in determining the cause-and-effect relationship in experimental models. The goal of variable control is to promote internal validity and make sure the result will be acquired only from the independent variable investigated (Karasar, 2015). To achieve this, the study attempted to equalize the experimental and control groups concerning different variables (gender, mathematics grade, cumulative grade point average [CGPA]). Each group has 28 students. The control group consisted of 13 girls (23.21%) and 15 boys (26.78%); the experimental group consisted of 14 girls (25%) and 14 boys (25%). We conducted an independent samples T-test to investigate the equivalence of other variables. We compared the gender of the experimental and control groups' students, the mathematics grades ($p=-.572$), the CGPA ($p=.175$), the AAT pre-test scores ($p=.475$), the ASTM pre-test scores ($p=-1.622$), the MAS pre-test scores, and the sub-factor pre-test scores ($p=.127$), and found that the experimental and control groups were statistically equivalent. While exemplifying student thoughts, which are qualitative data, students are represented with (S) and a number as S1, S2, ….

Data Collection Process

We implemented distinct teaching methods for the two groups based on the objectives of the study. The researcher is the role of the instructor in the experimental group, whereas the mathematics teacher teaches in the control group. Figure 1 shows the procedures in the experimental group:

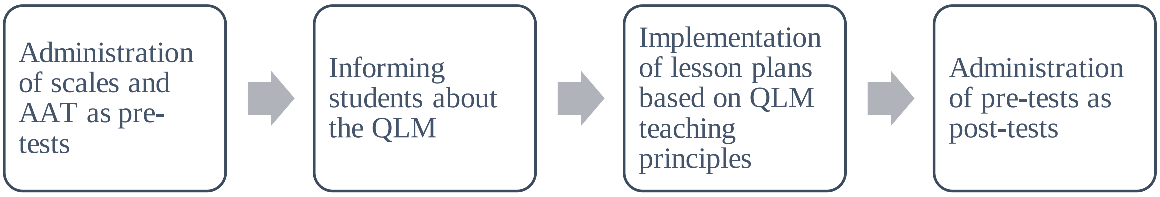

Figure 1. Procedures in the experimental group

The researcher announced that the 7/D class, designated as the experimental group, would receive instruction based on the QLM. The researcher asked students to bring a notebook and colored pencils to the lesson before starting the implementation. The implementation also required them to maintain a diary of the mathematics lesson. We have made efforts to prepare the classroom environment for quantum learning. We have arranged the desks for group work and prepared the board for activities. The implementation incorporates activities and pictures designed to enhance motivation. We employed quantum note-taking, reading, writing, and memory techniques throughout the experimental process. Additionally, the QLM covered techniques and methods such as problem-solving, brainstorming, and discussion. Music was used during some events. An example of the lesson plans used in the experimental group is provided in Appendix 1. We completed the experimental procedure in 7 weeks, adhering to the Ministry of Education curriculum.

We administered the control group to the students as pre-tests for two class hours before commencing the teaching session. According to the current program, which is based on the constructivist approach, the teacher reminds students of preliminary information about the subject and provides an environment where students can structure new information. The teacher employed techniques like question-answering, discussion, brainstorming, and narration in this environment. We reapplied the pretests as the posttest at the unit's conclusion.

Data Collection Tools

We used AAT, which consists of 22 questions; ASTM, which consists of 30 items; and MAS, which consists of 22 items in the current study. We also utilized student diaries, notebooks, and the researcher's diaries to gather qualitative data.

Academic Achievement Test (AAT)

Achievement tests are tests that measure how much a person has learned during an educational process or, in a broader sense, under environmental conditions (Tekin, 2008). We first determined the objectives related to the curriculum to prepare for the achievement test. We have prepared a multiple-choice test consisting of 44 questions. We investigated the content validity of the achievement test. Making a specification table containing subject-behavior comparisons for achievement tests gives important clues for content validity (Büyüköztürk et al., 2010). The table of specifications is a two-dimensional table that lists objectives with their behavioral aspects in one dimension and related questions in the second dimension (Turgut, 1995). The table of specifications determined the questions for the achievement test in this research, which measures the program's objectives (see Appendix 2). Experts reviewed the prepared test, administered it to 93 students not part of the study group, and conducted a statistical analysis of the results. We ranked the students' test scores from lowest to highest, thereby determining the 27% lower and upper groups. We applied an independent-samples-T test for the item analysis, eliminating and removing items (2nd, 8th, 12th, 15th, and 44th questions) that did not exhibit a meaningful difference in the ability to differentiate between the lower and upper groups. We examined the option distributions of the multiple-choice questions in the achievement test to determine the distracting power of the distractors. We entered the students' answers into the software. Item analysis was performed. We removed questions loaded with incorrect options (1, 14, 24, 27, 35, 36, 40) from the test. We used the most appropriate distractors in the test, leaving two questions for each outcome. We created an achievement test with 22 multiple-choice questions, determining their validity and reliability. Establishing validity is the first step toward seeking reliability. According to Yıldırım (1999), reliability refers to the accuracy with which a test or measurement tool measures its intended subject. The reliability analysis revealed a KR.20 reliability coefficient of .78 for this test.

Attitude Scale Towards Mathematics (ASTM)
We implemented ACTM, which was devised by Baykul (1990). The scale is a five-point Likert-type scale that is one-dimensional and comprises a collective sum of 30 items, 15 of which are positive and 15 of which are negative. For each item on the scale, five options will help determine the opinion regarding this question. These options include: "I totally agree (5 points)," "I agree (4 points)," "I am undecided (3 points)", "I disagree (2 points)," and "I totally disagree (1 point)." A minimum score of 30 and a maximum score of 150 are the results of the scale. We reapplied the scale as an attitude test to 56 non-participant students to retest its reliability and found the reliability coefficient to be .93.

Mathematics Anxiety Scale (MAS)
We used the MAS, which Şentürk (2010) developed. This is a 22-item, 5-point Likert-type scale used to measure mathematics anxiety. The possibilities for defining the level of anxiety on the scale items include "I always worry (5 points)," "I often worry (4 points)," "Sometimes I worry (3 points)," "I rarely worry (2 points)," and "I never worry (1 point)." The sum of these scores represents the student's mathematics anxiety score. Sub-factors are anxiety arising from attitude towards mathematics (1, 2, 3, 4), anxiety arising from lack of self-confidence (5, 6, 7, 8, 9), anxiety arising from lack of field knowledge (10, 11, 12, 13), anxiety towards learning (14, 15, 16, 17), and exam anxiety (18, 19, 20, 21, 22). To retest the scale's reliability, we reapplied it as an anxiety test to 56 non-participant students before the application and found the reliability coefficient as .90.

Data Analysis
We employed a significance level of .05 for the data analysis. We conducted an independent-samples-T-test to equalize the experimental and control groups and assessed the statistical significance of the difference between their means. We employed a paired-samples T-test to assess the mean differences between the pre-test and post-test scores within both the experimental and control groups. Then, we assessed the significance of the differences between the average scores of the post-tests and pre-tests.

Findings

1. Comparison of Achievement, Attitude, and Anxiety Variables in Experimental and Control Groups

Table 1 presents the independent-samples T-test results of the experimental and control groups.

Table 1.
Independent-Samples T Test Results for Achievement, Attitude, and Anxiety Post-tests Score Averages

Groups	N	$\overline{X}$	ss	SD	t	p
Experiment -Achievement	28	10.535	4.925			
Control-Achievement	28	7.785	3.326	54	2.448	.018*
Experiment- Attitude	28	94.678	27.794			
Control- Attitude	28	101.107	18.663	54	-1.016	.314
Experiment- Anxiety	28	53.642	19.955			
Control- Anxiety	28	56.321	12.504	54	-.602	.550

* p <0.05

In Table 1, there is a difference of 2.750 points in favor of the experimental group. When examining the p-value to ascertain the significance of the difference, p=.018. Since p<.05 is within the 95% confidence interval, the post-test scores exhibit a statistically significant difference. As a result, the high mean indicates a significant difference favoring the experimental group over the control group. In this case, it appears that the QLM is effective for academic achievement in the experimental group. In other terms, the QLM is more effective than the current approach for academic success.

Table 1 indicates that there is no statistically significant difference between the two groups' attitude post-test mean scores, as p=0.314>0.05 within the 95% confidence interval. Consequently, the post-test means scores of the groups in the attitudes show no notable distinction. Thus, we can infer that the QLM does not effectively modify attitudes towards mathematics lessons.

Table 1 presents that there is no statistically significant difference between the two groups' anxiety post-tests mean scores, as p=.550>.05 within the 95% confidence interval. As a result, the experimental group's low average score is in favor of the experimental group in terms of mathematics anxiety. However, the lack of a statistically significant difference suggests that the QLM does not effectively reduce mathematics anxiety.

2. Comparison of Gain Scores of Experimental and Control Groups

First, we investigated the differences between the achievement, attitude, and anxiety pre-test and post-test scores of the groups. Next, we compared the gain scores of each group for each variable.

Comparison of Achievement Scores

Table 2 presents the groups' pre-tests and post-test scores of achievements regarding the paired-samples T-test results:

Table 2.
Paired-samples T Test Results Regarding Academic Achievement

Groups	N	$\overline{X}$	ss	SD	t	p
Experiment (pretest)	28	5.714	3.740			
Experiment (posttest)	28	10.535	4.925	27	-5.495	.001*
Control (pretest)	28	5.250	3.575			
Control (posttest)	28	7.785	3.326	27	-5.957	.001*

*p<0.05

According to Table 2, there is a statistically significant difference between the pre-test and post-test scores averages of both the experimental group and the control group, as $p<0.05$ within the 95% confidence interval.

The experimental and control groups' academic achievements increased significantly. We examined whether there was a significant difference between the gain scores of the two groups. To calculate gain scores, we took the difference between the post-test and pre-test scores. We conducted an independent-samples T-test with the gain scores (see Table 3):

Table 3.
Independent-samples T Test Results Regarding Achievement Gain Scores of Groups

Groups	N	$\overline{X}$	ss	SD	t	p
Experiment	28	4.821	4.643			
Control	28	2.535	2.252	54	2.344	.024*

*p<0.05

In Table 3, the experimental group has a 2.286 score advantage in terms of the post-test averages of the groups. When looking at the p-value to decide whether this difference is significant or not, $p=0.024$. Since $p<0.05$ is in the 95% confidence interval, there is a statistically significant difference between the gain scores of the groups. The results show that the experimental group has a significant advantage over the control group due to its high mean. In this case, it appears that the QLM is effective in terms of achievement in the experimental group. To put it another way, the QLM outperforms the current approach in terms of achievement.

Comparison of Attitude Gain Scores

Table 4 shows the groups' pre-test and post-test scores of attitudes regarding the paired-samples T-test results.

Table 4.
Paired-samples T Test Results Regarding Attitude

Groups	N	$\overline{X}$	ss	SD	t	p
Experiment (pretest)	28	94.321	25.704			
Experiment (posttest)	28	94.678	27.794	27	-.200	.843
Control (pretest)	28	104.000	18.338			
Control (posttest)	28	101.107	18.663	27	2.619	.014*

*p<0.05

In Table 4, there is no statistically significant difference between the pre-test and post-test score averages of the experimental group, as p=0.843>0.05 within the 95% confidence interval. In the control group, there is a statistically significant difference between the pre-test and post-test score averages (p=0.014<0.05) within the 95% confidence interval. There is a difference of 2.893 between the pre-test and post-test averages in favor of the pre-test in the control group. In this instance, the current approach led to a statistically significant decrease in the average mathematics attitude score of the control group. The control group's low post-test mean score suggests a negative impact on their attitudes toward mathematics. We may attribute this negative effect to the control group's approach and the content that was taught.

We examined whether the attitude gain scores of the experimental and control groups showed a significant difference. We calculated the gain scores by taking the difference between the groups' post-test and pre-test scores. We conducted an independent-samples T-test with the gain scores. Table 5 presents the results.

Table 5.
Independent-samples T Test Results Regarding Attitude Gain Scores of Groups

Groups	N	$\bar{X}$	ss	SD	T	p
Experiment	28	.3571	9.452			
Control	28	-2.892	5.845	54	1.547	.128

According to Table 5, there is no statistically significant difference between the scores of the groups' attitude gain, as p=0.128>0.05 within the 95% confidence interval.

Comparison of Anxiety Gain Scores
Table 6 shows the groups' pre-test and post-test scores of anxiety regarding the paired-samples T-test results.

Table 6.
Paired-samples T-test Results Regarding Anxiety

Groups	N	$\bar{X}$	ss	SD	t	p
Experiment (pretest)	28	53.964	16.192			
Experiment (posttest)	28	53.642	19.955	27	.334	.741
Control (pretest)	28	53.464	13.237			
Control (posttest)	28	56.321	12.504	27	-3.845	.001*

*p<0.05

Table 6 shows that there is no statistically significant difference between the experimental group's pre-test and post-test score averages, as p=0.741>0.05 within the 95% confidence interval. Again, according to Table 6, the pre-test and post-test averages have a difference of 2.857 in favor of the post-test in the control group. Since p=0.001<0.05 within the 95% confidence interval, there is a statistically significant difference between the pre-test and post-test score averages of the control group.

In this case, the implementation of QLM in the experimental group resulted in a decrease in the average mathematics anxiety score, but this decrease was not statistically significant. The current approach significantly increased the average mathematics anxiety score of the control group. A high post-test mean score in the control group indicates increased anxiety. If students have learning difficulties with the contents of the unit, this may cause their anxiety to increase.

We examined whether the anxiety gain scores of the experimental and control groups differed significantly. We calculated the gain scores by taking the difference between the groups' post-test and pre-test scores. We conducted an independent-samples T-test with the gain scores. We present these results in Table 7.

Table 7.
Independent-samples T Test Results Regarding Anxiety Gain Scores of Groups

Groups	N	$\overline{X}$	ss	SD	T	p
Experiment	28	-.321	9.452			
Control	28	2.857	5.845	54	-2.612	.012*

*p<0.05

Table 7 shows a 3.178 difference between the experimental group's average gain score and the control group's average gain score in favor of the control group. There is a statistically significant difference between the post-test scores of the experimental and control groups (p=0.012<0.05) within the 95% confidence interval. In this case, the control group has a higher average mathematics anxiety score than the experimental group. This result indicates an increase in mathematics anxiety and a negative impact on the control group.

The Anxiety Scale for Primary School Mathematics Students consists of five sub-factors. Table 8 presents the results of the QLM's impact on the sub-factors in both the two groups.

Table 8.
Independent-samples T Test Results Regarding Anxiety Sub-factors' Gain Scores of Groups

Sub-Factors*	Group	N	$\overline{X}$	ss	SD	t	p
ARATM	Experiment	28	-.392	2.183	54	-.946	.349
	Control	28	.357	3.581			
AOSC	Experiment	28	.642	4.778	54	.726	.473
	Control	28	-.071	2.071			
AOSK	Experiment	28	-1.071	3.126	54	-1.259	.214
	Control	28	.035	3.447			
LA	Experiment	28	-.428	4.375	54	-1.696	.096
	Control	28	1.535	4.290			
EA	Experiment	28	.928	3.609	54	-.069	.945
	Control	28	1.000	4.100			

* ARATM=Anxiety Resulting from Attitude Towards Mathematics, AOSC=Anxiety Originating from Self-Confidence, AOSK=Anxiety Originating from Subject Knowledge, LA=Leaning Anxiety, EA=Exam Anxiety.

According to the analysis, there is no statistically significant difference between the average scores of the experimental and control groups on the sub-factors.

3. Instructor and Students' Opinions about the QLM

Throughout the implementation process, we asked students to keep diaries in which they expressed their feelings and thoughts about the mathematics course. Examining the student diaries revealed that students generally began to enjoy the mathematics lesson and found it fun. Students attributed this to the implementation of diverse activities like mind mapping, competitions, and poster preparation, which were absent in earlier courses. For example, S23 stated that the mathematics lesson went well and S28 indicated that completing the story was nice:

> Today's third and fourth lessons focused on mathematics. In mathematics, we use something called the quantum technique. Today, our teacher drew and colored fractions on paper. We selected two students from each group. Without speaking, one of our friends used fraction cards and hand signs to explain our teacher's multi-step process, while the other recorded his understanding on the board. That's it for this day. It was very nice. (S23)

> I'm very excited today. It was a very interesting lesson. I was in class for the second time today. We did a lot of activities today. We completed the story and drew numbers from the bag. How nice it would be if all classes were like this! (S28)

S27 emphasized playing games at the celebration phase "In today's lesson, we wrote our last writing about the coordinate system and played Admiral Sank. We had a good lesson, as always".

Upon examining the unfavorable comments in certain student diaries, it became evident that students encountered challenges in comprehending specific subjects. Since most of the activities were in the form of group work, not being able to speak was sometimes a problem for students who liked to work individually. For example, S21 and S8 stated that the subject was difficult. S21 stated, "We solved problems in math class again today. Then we moved on to another topic. But the questions were very difficult for me. I gained a basic understanding of the content". Similarly, S8 indicated "Today is a new topic, a new curiosity. The issue confused me from the very beginning. But then it felt fun... If only I could have the right to speak!"

In her diary, the instructor/researcher stated that students' interest and motivation in the course increased. She asserted that students' active participation in the course process and their use of note-taking techniques were highly beneficial for their learning:

> In today's lesson, we made a mind map for the first time. Since we were doing it for the first time, I prepared a draft mind map with the main branches. The students completed the sub-branches of the map, albeit with difficulty. I then told them that they could enrich this map with any shapes, symbols, signs, and colors they wanted. At the end of the lesson, very beautiful mind maps emerged. The students appear to be interested in quantum learning. However, the fact that the class is crowded and there are seven groups in the class makes classroom management difficult. I can acknowledge that there are challenges associated with group activities. Over time, I believe they will become accustomed to group work (Friday, March 4).
>
> Students can now effectively use quantum learning's note-taking techniques. Competition events bring them immense joy, and they take great pleasure in receiving awards during the celebration phase. Making posters is another activity they enjoy. Students enjoy creating a product in groups and displaying it on the board (Wednesday, April 6).

Figure 2 shows an example of students' mind maps and note-taking techniques:

(a) Example of mind map *(b) Example of note-taking technique*

Figure 2. Examples of Students' Mind Maps and Note-taking Techniques

Discussion, Conclusion, and Suggestions

The current research examined the effect of the QLM on mathematics teaching. We examined the significant difference in the academic achievement variable obtaining positive results in favor of the experimental group. The results of the current study align with the results of other investigations documented in the literature (e.g., Acat & Ay, 2014; Barlas, 2002; Benn, 2003; Demir, 2006; Güllü, 2010; Hanbay, 2009; Myer, 2005). This study demonstrates the effectiveness of effective note-taking techniques, mind maps, effective group work, and problem-solving skills. This may be due to its impact on academic achievement. Indeed, the studies (e.g., Ay, 2010; Demir, 2006; Güllü, 2010;

Hanbay, 2009) suggest that the activities, group studies, and effective note-taking techniques conducted within the framework of quantum learning may have enhanced students' metacognitive learning strategies more than the current mathematics curriculum. Bakır and Koç-Akran (2019), who investigated the effect of the QLM on students' problem-solving skills, discovered that the experimental group exhibited substantially superior problem-solving abilities in comparison to the control group. Ökmen et al. (2023) integrated the procedures of the problem-based learning approach with the quantum learning cycle. They stated that this model, which they applied to teacher candidates, was effective in helping the candidates gain teaching and thinking skills.

There was no significant difference in terms of attitude towards the mathematics course post-tests between the experimental and control groups, the difference between the pre-test and post-test within the groups, or gain scores. However, the post-test mean score decreased significantly in the control group. The decline observed in the control group may be attributed to the subject matter addressed in the unit. Regarding gain scores, there was no significant difference between the groups. Similarly, Şöhretli (2014), in his study using the QLM for teaching fractions, found a positive effect of the model on academic achievement but did not find a significant difference in students' attitudes towards mathematics.

There was no significant difference in terms of post-test anxiety towards the mathematics course between the experimental and control groups, the difference between pre-test and post-test within the groups, or gain scores. The experimental group experienced a decrease in post-test mean scores, which was not statistically significant, whereas the control group experienced a statistically significant increase in post-test scores. In other words, the implementation in the control group significantly increased the anxiety level of the group. We found a significant difference in gain scores between the groups. The experimental group's anxiety level did not suffer as much as the control group's due to the classroom environment's ability to motivate students, boost their self-confidence, and make the lesson enjoyable. Demir (2006) and Hanbay (2009) conducted a study that found an increase in students' interest in the course, an increase in their self-confidence, and a decrease in their learning anxiety. These results align with the findings of the study.

The students and the teachers have expressed positive opinions about the use of note-taking techniques and mind maps, which enhance the durability of learning, the establishment of a classroom environment and atmosphere conducive to QLM, and the implementation of celebration activities. Demirel (2004) and Ay (2010) found that the QLM positively affects learning behaviors. Several studies (e.g., Demir, 2006; Güllü, 2010; Hanbay, 2009) have found that it has a beneficial impact on the students' views of the course, school, learning, and themselves. In Bakır and Koç-Akran's (2019) study, students stated that thanks to quantum learning activities, the lessons were more fun, they took their notes, and thus their problem-solving, emotional intelligence, and collaborative learning skills improved. According to Alaca (2014), the note-taking technique, mind maps, listening to music, group activities, and games used in the quantum learning process make learning fun.

The teachers also expressed similar views as students. In Ay's (2010) study, the teachers stated that QLM had a positive influence on students' motivation, active participation in the lesson process, speed of understanding, and learning to learn. Additionally, according to Barlas (2002), teachers who engaged in this practice were more effective than traditional teachers because they enhanced the learning environment, incorporated a greater amount of music compared to traditional classrooms, acknowledged their students' learning achievements, and utilized visuals to facilitate students' thinking and memory retention. The negative views regarding quantum learning may be that students are not sufficiently accustomed to group work and that some contents in the unit require high-level cognitive skills such as problem-solving and reasoning.

The researcher's observations show that the QLM effectively may increase students' academic success. Activities must be well structured to prevent loss of time in the quantum learning process. It may take time for students to adopt the QLM during the transition. To facilitate this transition, it is crucial to motivate students, focus on the celebration phase, and arrange the classroom environment with posters that enhance their learning. In the QLM, the enrollment and association stages play a crucial role in grabbing students' attention. During these stages, one can incorporate discussions and watch presentations and videos. Creating mind maps that remind us of preliminary knowledge can be effective, especially at the association stage. Mind maps enable the establishment of relationships between key concepts and words, thus storing, organizing, and organizing information (Gömleksiz & Fidan, 2013). During the labeling phase, students can enjoy using effective note-taking techniques, which also ensures permanent learning.

In addition to the QLM's impact on students' cognitive and affective skills, Wajdi (2017) asserts that QLM has the potential to modify the behavior of children suffering from behavior disorders. The QLM would also enhance pre-service teachers' capacity to enhance their academic performance by engaging more of their brain functions, uncovering their learning strategies, and strengthening their knowledge. Nevertheless, it is imperative to instruct teacher candidates in QLM by providing them with efficient teaching approaches, it enables them to effectively instruct their students and aids in the retention of gained knowledge (Afacan & Güler, 2019).

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Appendices

Appendix 1. An Example of Lesson Plans Utilized in the Experimental Group

Grade: 7
Objective: Solves and poses problems related to rational numbers.
Recommended Duration: 3 Lesson Hours

Quantum Learning-Teaching Process Analysis:

Skills / Phases	Enrolling	Association	Labeling	Demonstration	Repetition	Celebration
Quantum work		x	x			
Quantum reading	x					
Quantum writing		x				
Quantum note taking/mind maps			x			
Quantum memory					x	
Eight keys of excellence		x				x
Communication skills				X		x
Problem solving		x	x			
Self-confidence		x			x	x
Leadership				X		
Responsibility						
Motivation	x				x	x
Outdoor lesson						x

Phase 1 Enrolling:

This stage starts with a reading about the history of rational numbers (Music during this stage can be used). This reading passage provides brief information regarding the use of rational numbers by the Egyptians, Romans, and Greeks. Following the reading, the teacher poses the questions to the students,

- "Is the use of rational numbers, which were also prevalent in past eras, truly essential? Today, where do we use rational numbers? Can we use rational numbers to solve the problems we face in our daily lives?

Phase 2 Association:

The teacher asks students to remember how to perform multi-step operations with rational numbers. She emphasizes that "the order is crucial, as it determines where to begin the operation. This order is also important when solving problems with rational numbers".

- Quantum Writing Exercise: Students are required to respond to the following questions:

1. What is a problem?
2. What is a mathematical problem?
3. What conditions must a situation meet in order to be a problem?
4. How do you plan to solve a problem?
5. Can you create a problem with rational numbers?

The students express their own thoughts by using their prior knowledge to answer the questions. They practice quantum writing while listening to background music. The teacher asks the volunteer students to read what they have written.

- Next, the teacher presents the below example and poses the following questions:

"A group of friends are looking for a place to camp in Uzungöl. They think that this campsite is suitable for one person. The fee is 25 TL. The applied tariff offers a discount as the number of days stays increases. We will apply a discount of 1/20 of the total fee if you stay more than 5 days, and a discount of 1/10 of the total fee if you stay more than 10 days. Here, a group is planning to stay for 7 days makes their payments on the first day. Then they decide to extend their stay for a few more days".

- Is this situation a problem?

The students must answer the following questions in order for a situation to be considered a problem:
1. Is there a clearly stated situation?
2. Is there a clear and unambiguous goal?
3. Do we have all the information to reach the goal?

Accordingly, the students are expected to explain that that there is a clearly stated situation but not a goal. The teacher provides the following example as a potential goal:
Goal: How much more would each group member have to pay according to the new plan?
The investigation then focuses on the answer to Question 3. We know the daily rate, the discount tariff, and that they pay for 7 days, but we don't know how long they extend the period afterwards. For example, we rephrase the problem by assuming that they have decided to extend it by 4 days. Therefore, the teacher explains that it is a problem.

Phase 3 Labeling:

The teacher instructs students to use the quantum note technique to take notes in their notebooks.

Task 1: Layers of the Atmosphere
The teacher provides the following information with details about the layers of the atmosphere.
"The atmosphere persists up to approximately 10,000 km above the ground. The layers of the atmosphere, as well as the height of some layers above the ground, are shown below.
1. The height above the ground of the upper limit of the troposphere is 1/625 times the height above the ground of the upper limit of the atmosphere.
2. The height above the ground of the upper boundary of the stratosphere is 3/1000 times the height above the ground of the upper atmosphere.
3. The height above the ground of the upper limit of the shemosphere is 9/1000 times the height above the ground of the upper limit of the atmosphere.
4. The height above the ground of the upper boundary of the ionosphere is 3/100 times the height above the ground of the upper boundary of the atmosphere."

The information above instructs students to solve the following problems in accordance with the stages of problem solving. Stages of problem solving:
Expressing in our own words
Identifying what is given
Planning-strategizing
Implement the plan
Verifying the solution

- Problem 1: How many kilometers above the ground is the height of the troposphere's upper boundary?
- Problem 2: How many km higher is the height of the upper boundary of the ionosphere above the ground than the height of the upper boundary of the stratosphere above the ground?

Task 2: How do we spend a day?
- Divide into groups of 4.
- Write down the activities you did during the day.
- Based on the fact that a day is 24 hours, express the time allocated to the activities as a rational number by proportioning it to 24.
- Show all activities on a table.
- Create one problem using these data,
- Ask (volunteer students) to solve the problems.

Phase 4 Demonstration:	Task 3: What can I buy in the canteen? Foods Bagel .....TL Toast ......TL .... Drinks Ayran ......TL Milk ......TL Fruit Juice.....TL .... Stationery .....TL Pen .....TL Eraser .....TL .... - Divide into groups of 4. - Find out the prices of some foods in the canteen at break and prepare a list. - Show different options how a student with 12TL can spend his/her money in such a way that he/she spends at most 1/3 of it on food, at most 1/6 of it on drinks, at most 1/4 of it on stationery, and the rest on other things he/she needs or on savings. - Pose a problem with this data. - Make a presentation as a group.
Phase 5 Repetition:	The teacher asks the students to summarize the prerequisites for a situation to be a problem, and the steps of a problem-solving process. She asks students to write a quatrain on the subject to make it more permanent and enjoyable. Example: Let problems fear me. I'll solve them in no time. First I make my plan. Then I'll carry out my plan Every statement I make is clear. I have a goal, too. All of the necessary information is also available. What can be done to solve this problem?
Phase 6 Celebration:	The teacher thanks the students for their efforts in the activities and encourage them to study. With reading the quatrains they have fun in the classroom.

Appendix 2. Table of Specifications

Objectives*	Questions																					
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22
1.Performs multi-step operations with rational numbers.	x	x																				
2. Solves and poses problems related to rational numbers.			x	x																		
3. Describes linear equations.					x	x																
4. Explains and uses the Cartesian coordinate system.							x	x														
5. Draws the graph of linear equations.									x	x												
6. Finds the factorials of whole numbers.											x	x										
7. Explains the concept of permutation and calculates it.													x	x								
8. Determines the experiment, sample space and event of dependent and independent events.															x	x						
9. Explains the dependent and independent events.																	x	x				
10. Calculates the probability of dependent and independent events.																			x	x		
11. Calculates the probability of an event using geometry.																					x	x

* The objectives were included in the Ministry of National Education's 2011 Middle School Mathematics Curriculum.