MS RESEARCH THESIS

THE EFFECT OF QUANTUM TEACHING METHOD ON MATHEMATICS REASONING SKILLS AT ELEMENTARY SCHOOL STUDENTS

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A thesis submitted in partial fulfillment of the requirement for
the degree of MS Teacher Education

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By

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This thesis has been accepted by the Department of Teacher Education, Faculty of Education, International Islamic University Islamabad in partial fulfillment of the degree of **MS Teacher Education**.

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AUTHOR'S DECLARATION

It is hereby declared that author of the study has completed the entire requirement for submitting this research work in partial fulfillment for the degree of MS Teacher Education. This thesis is in its present form is the original work of the author except those which are acknowledged in the text. The material included in the thesis has not been submitted wholly or partially for award of any other academic certification than for which it is being presented.

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SUPERVISOR'S CERTIFICATE

The thesis titled "The Effect of Quantum Teaching Method on Mathematics Reasoning Skills at Elementary School Students" submitted by Ms. Muqaddas Subhan Reg. No. 6-FOE/MSTE/F23 is partial fulfillment of MS degree in Teacher Education, has been completed under our guidance and supervision. I am satisfied with the quality of student's research work and allow her to submit this for further process as per IIUI rules and regulations.

Dr. Zarina Akhtar

Dedication

I dedicate this thesis to my beloved parents, who have always supported me with their love, prayers, and care. Their sacrifices and encouragement gave me the strength to reach this point. I am also thankful to my teachers and supervisors for their guidance, knowledge, and kind support throughout my research. Finally, I dedicate this work to the students who took part in this study, their interest and cooperation gave real purpose to my research.

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Abstract

The Quantum Teaching Method (QTM) is an innovative instructional approach that blends multiple teaching strategies to create engaging, brain- compatible learning environments that promote deeper understanding and reasoning. In elementary mathematics education, where conventional methods often prioritize traditional method, QTM offers a more interactive and student-centered alternative that supports the development of mathematical reasoning skills. This study aimed to examine the effect of the Quantum Teaching Method on the mathematical reasoning skills of Grade IV students and compare its effectiveness with the traditional Direct Instruction method. A quasi-experimental design was used, specifically a pretest-post-test control group design. The study was conducted at Islamabad Model College for Boys, Sihala Sector, involving a sample of 62 Grade IV students, who were randomly assigned to two groups: the experimental group (n = 31) received instruction using the Quantum Teaching Method, while the control group (n = 31) was taught using the traditional Direct Instruction method. The intervention lasted for eight weeks, and both groups were assessed through a researcher-developed multiple-choice test measuring mathematical reasoning skills, administered as both a pretest and a post-test. Data analysis included descriptive statistics (mean, standard deviation) and inferential statistics (independent samples t-test and paired t test). Results revealed that the experimental group significantly outperformed the control group in the posttest, indicating a substantial improvement in mathematical reasoning skills due to the use of QTM. These findings suggest that the Quantum Teaching Method is more effective than traditional teaching methods in enhancing critical thinking and reasoning among elementary students. The study concludes that integrating the Quantum Teaching Method into elementary school curricula can significantly improve students' mathematical reasoning. It recommends teacher training programs focused on QTM strategies and further research exploring its long-term impact and effectiveness across different subjects and student populations.

Key Words: *Quantum Teaching Method, Mathematical Reasoning Skills, Direct Instruction, Quasi-Experimental Design, Elementary Mathematics*

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LIST OF ABBREVIATIONS

FDE	Federal Directorate of Education
HOTS	Higher Order Thinking Skill
IIUI	International Islamic University Islamabad
MRS	Mathematical Reasoning Skill
MRT	Mathematical Reasoning Test
QTM	Quantum Teaching Method
TIMSS	Trend in International Mathematics and Science Study
TOS	Table of Specification
EELDRC	Enroll Experience Label Demonstrate Review Celebrate
NCTM	National Council of Teachers of Mathematics
TIMSS	Trends in International Mathematics and Science Study
IMCB	Islamabad Model College for Boys
ICT	Information and Communication Technology
TANDUR	Tumbuhkan, Alami, Namai, Demonstrasikan, Ulangi, Rayakan
ZPD	Zone Of Proximal Development

CHAPTER 1

INTRODUCATION

Mathematics is Important for building critical thinking and problem-solving capacity that are mandatory for succeeding in today's complex and fast developing world. at the elementary level, many students face challenges due to traditional teaching methods that focus on retain answers rather of understanding the math problem and the reasoning beyond each step, which can affect their overall mathematical reasoning skills. Such circumstances can lead to difficulties in applying concepts to ongoing problems which can affect their long-term academic achievements. Mathematical reasoning skills are the 21st century skill, there is a growing require for advanced teaching methods that can successfully address these challenges. One such method is quantum teaching method, which aims to plan a more engaging and collaborative learning environment by integrating dynamic teaching instruction. This study explores the effect of quantum teaching methods on student mathematical reasoning skills among elementary students, providing understanding how modern teaching method can overcome the limitation of traditional teaching methods.

Mathematical reasoning is a fundamental skill that enables learners to think logically, analyze relationships, solve problems, and justify their thinking. It plays a key role in helping students understand mathematical concepts deeply, rather than just performing procedures. According to the National Council of Teachers of Mathematics, mathematical reasoning allows students to draw conclusions from patterns, make sense of mathematical ideas, and apply knowledge to new situations **(**Anthony & Walshaw, 2023**)**. These skills are especially important at the elementary level, where foundational understanding is developed. Unfortunately, many students struggle with reasoning tasks due to instruction that emphasizes rote learning over meaningful thinking.

In many Pakistani classrooms, traditional teaching methods continue to dominate, where teachers deliver content through lectures, and students are expected to memorize formulas and follow fixed steps to solve problems. This method often ignores the "why" behind the process, leading to surface-level understanding and limited reasoning ability (Gürbüz & Birgin, 2012). As a result, students may be able to solve routine problems but fail to explain their solutions or apply concepts in new contexts. Strengthening mathematical reasoning at the elementary level requires active teaching methods that promote student engagement, critical thinking, and reflection.

The Quantum Teaching Method (QTM) was developed in the early 1980s by Bobby DePorter, an American educator and co-founder of Super Camp a residential learning and life skills program designed for teenagers. Super Camp was established in 1982 and served as a practical learning laboratory where innovative teaching techniques were tested and refined. The purpose of the program was to help students improve not only in academics but also in personal and interpersonal development. Bobby DePorter and her colleagues noticed that many traditional teaching methods lacked engagement, emotional connection, and long-term retention. In response, they began integrating strategies from accelerated learning, brain-based education, and multiple intelligences to create a more dynamic, student- centered learning experience. These early efforts formed the foundation of what would later become known as Quantum Teaching (Wahyuni & Arifin, 2023).

The inspiration for Quantum Teaching was deeply rooted in the principles of Accelerated Learning**,** particularly those introduced by Dr. Georgi Lozanov, a Bulgarian educator and psychologist. DePorter adapted these ideas and combined them with other research-based practices to form a new approach that focused not just on what students learn, but *how* they learn best. She emphasized the importance of emotional safety, student involvement, and creating a learning environment that engages both hemispheres of the brain. These ideas were practically applied during Super Camp sessions, where students consistently showed higher motivation, improved academic performance, and better collaboration skills when taught using this method.

Although the ideas behind Quantum Teaching emerged in the 1980s, the method was formally introduced to the academic community through the publication of the book Quantum Teaching: Orchestrating Student Success in 1999 by Bobby DePorter, Mark Reardon, and Sarah Singer-Nourie. This book presented the Quantum Teaching framework in a structured way and introduced the widely used TANDUR model, which stands for Enroll, Experience, Label, Demonstrate, Review, and Celebrate. Each stage of TANDUR guides teachers on how to organize the learning process to help students emotionally connect with content, understand it deeply, and celebrate their learning achievements. The model encourages the use of interactive, experiential, and reflective strategies that are aligned with the way the brain naturally learns (Wahyuni & Arifin, 2023).

The term "Quantum" in this context refers to a leap in the quality and energy of teaching drawing from the idea of a "quantum leap" rather than quantum physics. It symbolizes a transformational shift from passive, teacher-centered instruction to active, brain-compatible learning. Quantum Teaching incorporates principles of multiple intelligences, whole-brain learning, rhythm, music, movement, and positive classroom culture to create an engaging and effective learning environment. Its goal is not only to improve academic outcomes but also to build students' confidence, creativity, and collaboration. Today, Quantum Teaching is used internationally in various school systems and training programs to create meaningful learning experiences that last beyond the classroom.

Several studies have shown that teaching methods based on active learning and student engagement can enhance problem-solving, critical thinking, and reasoning abilities (Rahmawati, 2023). However, limited research exists on the application of the Quantum Teaching Method in elementary mathematics classrooms, particularly in the context of public schools in Pakistan. This study aims to fill that gap by investigating the effect of the Quantum Teaching Method on students' mathematical reasoning skills, focusing on key skills such as comparing, contrasting, generalizing, and justifying. The results of this study may contribute to improved classroom practices and curriculum reforms aimed at developing thinking skills among young learners.

1.1 Background of Study

Mathematical reasoning is a fundamental cognitive skill that enable individuals to analyze interpret and solve by applying mathematical concepts and logic it is the process of making sense of mathematical situations identifying patterns and drawing logical conclusions mathematical reasoning goes beyond mere computation or memorization of formulas it involves critical thinking the ability to justify solutions and the capacity to make connections between different mathematical ideas.

At elementary level developing mathematical reasoning skills is crucial as it forms for more advanced mathematical learning and problem solving in later stages of education these skills are not only vital for success in mathematics but are also transferable to other disciplines where logical reasoning and critical thinking are essential in a study researcher found that who develop strong mathematical reasoning abilities are better equipped to approach problems in science technology engineering and even in every days decision-making (Rohati, Kusumah, & Kusnandi, 2023).

The development of mathematical reasoning skills in elementary school students is often hindered by traditional teaching methods that emphasize rote learning and procedural knowledge these methods typically focus on the correct execution of algorithms and the memorization of mathematical facts with less attention given to understanding underlying concepts or encouraging students to think about the problem they are solving. As results students may learn to perform calculations correctly but they often struggle to explain their reasoning their answers or apply their knowledge to new and unfamiliar problems (Öz & Işık, 2024).

To address these challenges, innovative approaches like Quantum Teaching have been introduced. Quantum Teaching is an educational method that emphasizes an integrated learning approach, incorporating various instructional strategies to support different learning styles. This method promotes not only the subject matter but also the cognitive and emotional aspects of learning, such as motivation and confidence (Supriadi et al., 2024).

According to Nurmalisa, Kune, and Ristiana (2022) that, students implementing Quantum Teaching reported a high engagement level of 81% instead to 72% in traditional teaching, showing that this method promotes active participation. The method is based on the concept that "everything speaks," which indicates that every element of the classroom from the setting to the teacher's nonverbal action transfer important messages to the students. This comprehensive method aims to increase student achievement while also fostering a passion for education.

In today's educational environment quantum teaching is important because it raises student engagement and encourages active involvement which improve the effectiveness of learning. By beginning inner links between the curriculum and students' involvement This model pushes teachers to create attract Classroom environments that increase understanding and recall. one study found that the academic performance of fourth grade student improved from a score of 68.81 to 8436 after the implementation of the quantum teaching model (Fadhilah et al. ,2022). And the model encourages creativity and critical thinking capacity which helps with holistic growth and makes it appropriate to a variety of subjects, incorporate social studies. For the development of students their critical thinking and problem-solving capability, mathematical reasoning is Important. Studies show how important instructional methods are in growing these abilities. In this study two teachers Tulay and Eda are compared in their teaching Tulay, who provided fewer freedom of choice for these components, Eda was more successful in sympathetic creative reflection, reasoning, and mathematical support according to research comparing the two professors. To direct these challenges, it is important for teachers to obtain support and instruction to increase their teaching methods and significant support to students' reasoning development (Öz & Işık, 2024).

Mathematical reasoning is a crucial skill for elementary school student forming the foundation for future academic and problem-solving abilities. Traditional teaching often emphasizes automatically learning which may not fully engage students or develop deep reasoning skill. Quantum method which focuses on interactive and student- centered learning offer a promising alternative. However, there is limited empirical evidence comparing the effectiveness of quantum teaching methods to traditional approaches in enchanting mathematical reasoning. This study aims to fill this gap by evaluating and comparing quantum teaching method traditional teaching method in grade 4 students from IMCB in the Shila sector of Islamabad

1.2 Problem Statement

Elementary students face challenges to develop mathematical reasoning skills due to traditional teaching methods that focus on retain answers rather of understanding the math problem This method limits student understanding the development of mathematics reasoning skills essential for-effective problem-solving in mathematics. As they can solve the problem, but they are unable to justify why certain steps are taken and why a specific method or formula is applied to solve the problem. Further they don't know which other way can be used to solve the problem, this is because of traditional method of teaching. Traditional methods often perform poorly in tasks in mathematics requiring deep conceptual understanding and logical reasoning. Addressing this problem is critical and it directly affects students' academic success This study aims to investigate the effect of Quantum Teaching method a collaborative and student- centered method, in improving mathematical reasoning skills differentiate to traditional methods. By recognizing more effective methods for elementary level mathematics strategies, this research seeks to encourage better comprehension and problem-solving capacity among student.

1.3 Objectives of the Study

The objectives of this study were to:

1. Investigate the mathematical reasoning skills of students at elementary level.
2. Find out the effect of quantum teaching method on students mathematical reasoning skills at elementary level.
3. Find out the effect of traditional teaching method (direct instruction method) on students mathematical reasoning skills at elementary level.
4. Compare the effect of quantum teaching method with traditional teaching method for student mathematical reasoning skills.

1.4 Research Questions

Research questions are:

1. What is the level of mathematical reasoning skills of elementary school students.
2. What is the effect of Quantum teaching method on mathematical reasoning skills of elementary school students.

1.5 Hypothesis of the study

H_{01}: there is no significant effect of quantum teaching method on mathematical reasoning skills of elementary school students.

1.6 Significance of Study

Studying the effect of quantum teaching method on elementary level student in Islamabad is significant as it can lighten how this method can affect mathematic reasoning skills in specific context. This research will provide insight to teacher whether quantum teaching method enhance student mathematical reasoning skills and engagement, and how it can be applied in daily classroom practices. Student may benefit through increased interest better conceptual understanding and improved problem-solving abilities in mathematics. For parents the study can highlight how active and engaging teaching method positively impact their children's learning progress. The findings can also support teacher education programs by offering practical evidence on effective strategies that promote reasoning and critical thinking. Additionally, it may assist curriculum developers in designing more interactive and learner centered mathematics content suitable for elementary learners.

Overall, this study aims to promote more effective and engaging method for teaching mathematics at the foundational level.

1.7 Delimitations

This study was delimited to:

1. Grade IV students of Islamabad model college for boy at Pakistan town in Islamabad
2. The study was focused specifically on the Mathematics Mysteries for grade 4 1^{st} edition.
3. The chapters included from prescribed book were Unit 4The Factor Forest and Multiple Mountains Adventure includes the topics: Divisibility Rules, Factors and Multiples, and Prime and Composite Numbers. And Unit 5 Fraction Frenzy in Fractionville covers Converting Fractions, Comparing and Ordering Unlike Fractions, Adding Fractions, Subtracting Fractions, and Multiplying and Dividing Fractions & Real-World Fraction Problem Solving.
4. The study was specifically focused on assessing the following sub variables of mathematical reasoning skills. Comparing contrasting generalizing justifying.

1.8 Operational Definitions

1.8.1 Quantum Teaching Method

The quantum teaching method is an educational approach that integrates multiple teaching strategies and learning style to create a dynamic engaging and supportive learning environment. It is designed to enhance student learning by leveraging principles of whole brain learning multiple intelligence.

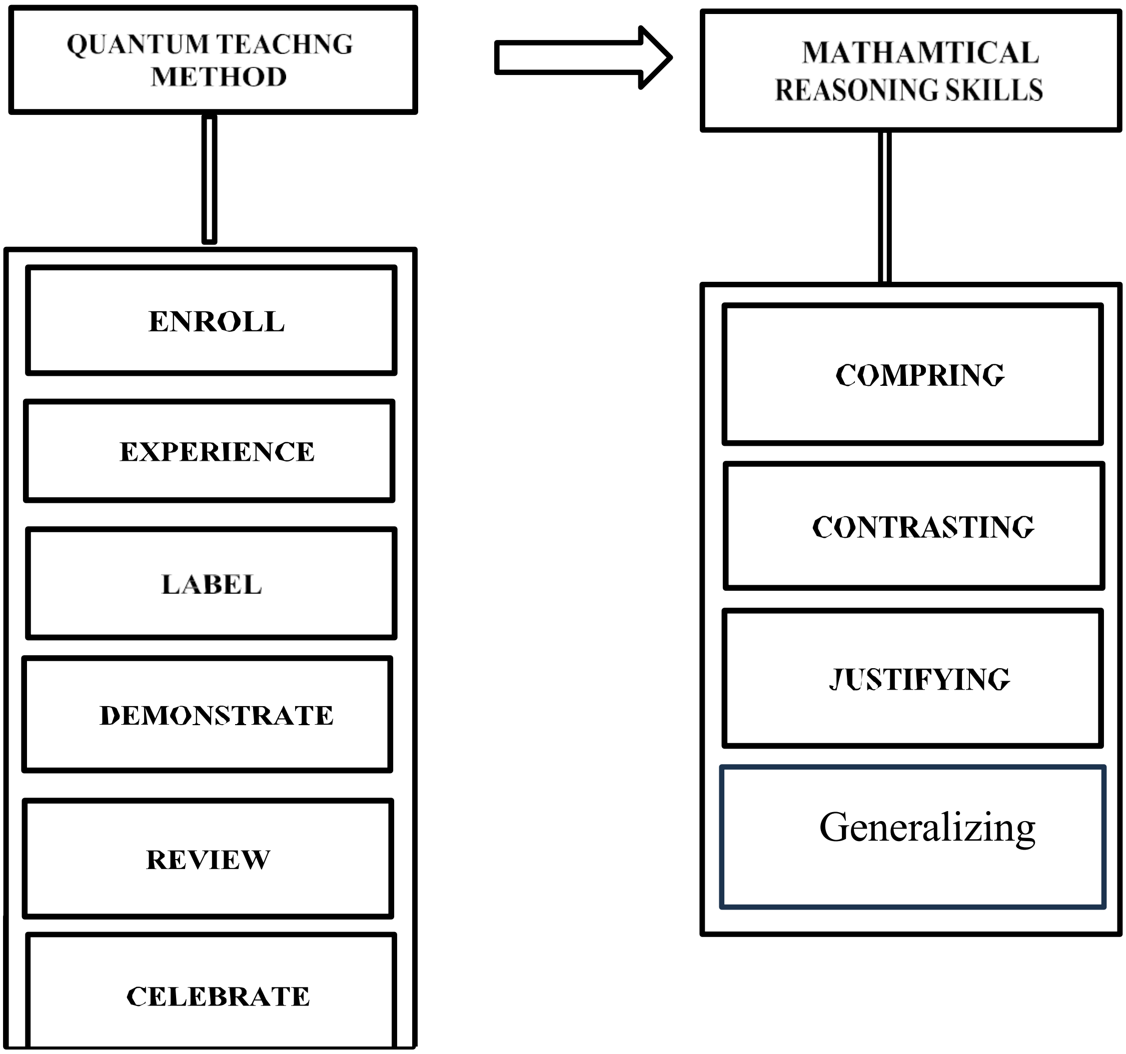
1.8.2 Mathematical Reasoning Skill

Mathematical reasoning skills refers to the abilities to analyze interpret and logically approach mathematical problems and concepts these skills are crucial for understanding and solving mathematical task as they involve the ability to think critically recognize patterns make connections and apply mathematical principles in various contexts.

1.9 Conceptual Framework

Figure1.1

Conceptual framework



Nabila, (2024). The effectiveness of Quantum Learning method in fostering students' writing ability on descriptive text in the tenth grade.

In this study, the Quantum Teaching Method (QTM) is the independent variable and is explained through its six TANDUR stages: Enroll, Experience, Label, Demonstrate, Review, and Celebrate. Each stage contributes uniquely to the development of mathematical reasoning skills. The Quantum Teaching Method (QTM), through its TANDUR stages, directly supports the development of mathematical reasoning skills. In the Enroll stage, students' attention and motivation are captured, encouraging them to compare new mathematical ideas with prior knowledge. The Experience stage provides hands-on activities and problem-solving opportunities that help learners contrast strategies and begin to generalize patterns. During the Label stage, concepts are formally named and organized, strengthening classification and generalization of relationships. The Demonstrate stage requires learners to explain and present their understanding, which develops their ability to justify solutions and defend conclusions. In the Review stage, concepts are revisited and connections are reinforced, enabling students to compare methods, draw conclusions, and refine generalizations. Finally, the Celebrate stage builds confidence and persistence, which indirectly enhances students' willingness to justify their reasoning and apply generalizations to new problems. Collectively, these stages foster comparing, contrasting, generalizing, and justifying, thereby systematically nurturing mathematical reasoning skills in a learner-centered environment.

CHAPTER 2

LITERTURE REVIEW

Developing strong mathematical reasoning skill is important for student at elementary level as it serves as the foundation for their future success in mathematics. Mathematical reasoning skill refers to the ability to think logically recognize patterns and apply mathematical principles to solve problems. Traditional teaching method often fails to adequately engage student or promote deep understanding of mathematical concepts. This has led educators to explore innovative instructional method such as the quantum teaching method, which aims to enhance student engagement and improve learning outcomes.

Quantum teaching is based on brain -based learning principles, incorporating a range of sensory and emotional stimuli to create a more dynamic and interactive classroom experience. By using techniques like storytelling music and hand -on activities, quantum teaching aims to make learning more enjoyable and effective (Devi, 2024). This literature reviews the effect of quantum teaching method on student mathematical reasoning skills, summarizing existing research and identifying gaps for future study

2.1 Understanding Quantum Teaching and its Foundations

Quantum teaching metho d is an educational approach that was first developed by bobbi deporter in 1990s. It is a student- centered method that draws on principles of accelerated learning and multiple intelligences theory. The core idea behind quantum teaching is that learning should engage multiple senses and emotions to make it more memorable and meaningful (Wahyuni & Arifin, 2023).

2.1.1 Principles of Quantum Teaching

Key principles of quantum teaching are following

1. Everything speaks: the idea that every element in the classroom including the environment teacher behavior, and instructional materials affect learning
2. Every is on purpose: each element of the lesson is intentionally designed to meet specific learning goals.
3. Experience before label: student experience aconceptfirst, before it is formally named or explained helping them from personal connections to the material.

4. Acknowledge every effort: Positive reinforcement motivates student to keep striving and engaging with the material.
5. Celebrate learning: celebrating small victories helps boost student confidence
6. and reinforce learning.

By integrating these principles, quantum teaching creates a lively classroom atmosphere that encourage student to participate actively, which is especially beneficial for subject like mathematics that require deep concentration and logical thinking.

2.2 Review of Related Literature

2.2.1 Quantum Teaching to Improve Math Learning Outcomes

Improving student engagement and learning outcomes in mathematics requires teaching Approaches that connect academic content to students' real-life experiences and encourage active participation. The Quantum Teaching Learning Model (QTLM) offers a structured framework designed to achieve these goals through its TANDUR stages: Tumbuhkan (Engage), Alami (Experience), Namai (Label), Demonstrasikan(demonstrate), Ulangai (Repeat), and Rayakan (celebrate). This approach aims to create meaningful learning experiences that build motivation and understanding. A classroom action research study in an Indonesian high school Demonstrated the effectiveness og QTLM in enhancing mathematics learning outcomes. Jayantika, Parmithi, and Dyanawati (2019) conducted in class X MIA 1 at senior high school PGRI 4 Denpasar with 46 students. The study was executed in two cycles each comprising planning, implementation, observation and reflection phase. Learning activity data were collected via structured observation sheets while mathematics learning outcomes were assessed through test instrument. The first cycle emphasized the application of the quantum teaching tandur model, which includes six stages Tumbuhkan (Engage), Alami (Experience), Namai (Label), Demonstrasikan(demonstrate), Ulangai (Repeat), and Rayakan (celebrate). These stages were strategically designed to create meaningful learning experiences by connecting academic content with students' personal lives and prior knowledge.

In the first cycle the researchers noted an 8.1% improvement in learning activity and a 4.83% increase in mathematics test scores compared to initial baseline observations however despite the positive trends certain challenges remained particularly students' reluctance to activity participate in group discussions a lack of confidence in presenting results and teachers limited use of real life applications in mathematical examples these shortcomings were addressed in the second cycle through enhanced contextualization of concepts targeted motivation strategies and peer support mechanisms.

The second cycle demonstrated a more substantial improvement learning activity score. Increased by 10.79% and mathematics learning outcomes improved by 8.38% from the previous cycles. The inclusion of daily life application in mathematical problems proved to be a critical factor in enhancing students' engagement and conceptual understanding. Additionally, the structured phase of QTLM fostered a positive learning atmosphere were student felt supported encouraged and motivation to participate more fully in their own learning process.

The study provides strong empirical evidence that QTLM can significantly enhance both cognitive and affective dimensions of mathematics education. By actively involving students in contextualized learning and promoting collaborative exploration the model aligns closely with key pedagogical principles such as constructivism and student-centered learning. the application of motivational reinforcement in the celebrate phase further contributed to building learners confidence and self-efficacy.

For researcher and partitioners focused on primary and secondary education particularly in mathematics this study offers valuable insights into how the implementation of quantum teaching can overcome common instructional barriers the finding suggests that integrating real world relevance and structured engagement phases into lesson planning not only improves academic performance but also nurtures more meaningful student teacher interactions and peer collaboration.

2.2.2 Quantum Teaching Hypnoteaching-Based Instruction

Enhancing mathematical understanding and reducing learning anxiety are important goals in teacher education programs. One effective approach for achieving these outcomes is the quantum teaching model combined with motivational techniques. Novianti and Mulyaning (2020) conducted a quasi-experimental study to evaluate the effectiveness of a quantum teaching model enhanced by Hypoteaching Teaching (QTH) in improving mathematical understanding among students in an elementary teacher education program. A sample of 50 participant was divided into an experimental group receiving QTH instruction and a control group receiving traditional instruction. The study used t-tests for data analysis and found the QHT group achieved significantly better outcomes in mathematical understanding, particularly among students with medium and low initial ability levels.

The QTH approach not only improved cognitive comprehension but also reduced students learning anxiety and increased their motivation by creating a supportive psychological environment. the Quantum teaching Structure ensured a contextual link between abstract mathematical concepts and real-world applications while the hypoteaching component encouraged deeper focus and emotional engagement. This dual approach led to stronger cognitive retention and greater active participant. Student exposed to QHT also demonstrated better performance on posttests and reported higher self-efficacy. These finding suggest that integrating motivational strategies like hypo teaching with in the QTM framework can enhance its effectiveness especially in preparing future elementary school teachers who will later apply these methods in their classrooms.

2.2.3 Quantum Teaching and Motivation on Science Learning Achievement

In elementary education improving students' academic achievement requires teaching approaches that address both cognitive development and emotional engagement motivation is and critical factor that address both cognitive development and emotional development. Motivation is and critical factor that can influence how well student learn but effective teaching strategies must also provide structure relevance and opportunities for active participation. One approach that combines these elements is the quantum. Teaching model which is designed to create students centered interactive and engaging learning environments this approach has been studied for its ability to improve not only academic performance but also students' motivation and overall learning experience

Zaroha, Firman, and Desyandri (2018) investigated the combined effect of quantum teaching and school learning motivation on science achievement in a sample of Grade V emelnetry school students. the quasi-experimental study employed and 2x2 factorial design involving 60 students divided into an experimental and control group the experimental group received instruction through the quantum teaching model while the control group followed conventional teaching method both cognitive and effective domains were measured through learning outcomes test and motivations questionnaires.

The results indicated that students taught using quantum teaching strategies outperformed those taught using conventional methods in all three domains cognitive affective and psychomotor. The findings also showed that students with both high and low motivation levels benefited more from quantum teaching compared to their counterparts in the control group interestingly there was no significant interaction between motivation and teaching strategy suggesting that QTM independently contributes to improved academic performance regardless of and students' initial motivation level.

The researcher attributed these results to the interactive students centered nature of QTM. The method emphasized enjoyments contextual learning and emotional involvement factors know to boost comprehension and retention. The use of varied teaching aids group collaboration and reinforcement through slogans and celebrations created and dynamics and inclusive classroom environment. These attributes helped enhance not only subject mastery but also students' enthusiasm and confidence

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The researchers attributed these results to the interactive, student-centered nature of QTM. The method emphasized engagement, contextual learning, and emotional involvement—factors known to boost comprehension and retention. The use of varied teaching aids, group collaboration, and reinforcement through slogans and celebrations created a dynamic and inclusive classroom environment. These attributes helped enhance not only subject mastery but also students' enthusiasm and confidence. Thus, this study further validates the effectiveness of Quantum Teaching in promoting holistic educational outcomes, particularly in elementary-level science education.

2.2.4 Scientific-Based Quantum Learning Models in Elementary School

The development and implementation of a scientific based quantum learning Model tailored for elementary school setting, the study addressed the challenges teacher pays and maintaining student engagement and improving knowledge retention.by using Qualitative methods. Including interviews and classroom observation, the author identified A lack of student motivation. Passive learning environment and difficulties in conceptual understanding is recurring problem in traditional classroom (Ariftian, Madjdi, & Murtono, 2021).

To overcome this issue, the researcher proposed a structured learning model integrating quantum teaching with scientific. Learning principle. This model named TANDU KUSIR, Consistence of nine phase, grow, experience, name, demonstrate, repeat, strengthen feedback. Conclude and celebrate. Each phase aims to foster student engagement through curiosity, experience, experiential learning. Conceptual development. Peer attention. Reinforcement and celebration.

The study highlighted the model potential to create a stimulating and inclusive learning environment. Observation showed improved classroom participation, higher motivation, and deeper comprehension of the subject matter among students exposed to this model. Importantly, the model also allowed for flexible adoption to various subject and student needs, promoting both academic and emotional growth. These findings support the broader. Applicability of quantum teaching, especially when paired with evidence based scientific method.

2.2.5 The Use of Quantum Teaching to Improve Mathematics Learning in Early Grades

The use of quantum teaching to improve mathematical learning and early grades. Improving mathematic learning and early grades require engaging and student center approaches that help build understanding through active participation. Quantum Teaching. Offer one such model that emphasizes structured interactive phase. To support young learner. Roviani (2023) Conducted classroom action to examine the effect of quantum teaching. On mathematic learning outcome and grade II at SDN 158/Vlll Rimbo Mulyo. The study focused on time measurement Is the main subject matter. The research involved 33 students and was carried out in two cycles with each cycle including planning, action, observation and reflection phase.

In the priest cycle stage only 42.42%. Of student met the minimum mastery criterion (KKM=70) within average score of 61.21 after implementing the quantum teaching model in cycle one the average score increased to 67.88. With 60.61%. Mystery in cycle 2.

Further improvement was observed. Within every score of 73.03 and 81.81% of students achieving mastery, The model structured phase. Help increase student engagement, understanding, and retention the use of. Visual tool like flash card and group discussion also contributed to better learning experiences. The study concluded that the quantum teaching model positively impacted student outcome and engagement in mathematics at the primary level. The study concluded that the quantum teaching model positively impacted student outcome and engagement in mathematics at the primary level. The model cycle. The model cyclical Structure and. Emphasizes on active participation provided account. Emphasizes on active participation provided a concrete and enjoyable learning process. And enjoyable learning process. Providing especially beneficial for lung learner. Providing especially beneficial for young learner.

2.2.6 Effect of Quantum Learning Model on Higher Order Thinking Skills

Developing High Order Thinking Skills (HOTS) in elementary education requires instructional model that foster creativity, analysis and critical reflection. Quantum learning, with its active, students -centered approach, his shown promise in supporting these goals. Pratama and Solehuddin (2019) examine the impact of Quantum learning model on the development of high order technical skill (HOTS) among grade IV elementary students. Employing a quasi-experimental design with pre-test and post-test control groups, the study found that the experimental group demonstrated a significant improvement in HOTS, particularly in analysis, evaluation and creation, compared to the central group.

Model created a joyful in student centered environment that encouraged active engagement and intellectual risk talking structured around the. Model created a joyful in student centered environment that encouraged active engagement and intellectual risk talking structured around the TANDUR Framework. The instruction emphasized experiential learning, reflection, and celebration. The study concluded. The study concluded. The quantum learning is. The quantum learning is. Especially. Effective and cultivating critical. Effective and cultivating critical And Creative thinking, making it a suitable pedagogical approach. Creative thinking, making it a suitable pedagogical approach. For promoting HOTS in elementary education.

2.2.7 Enhancing Mathematics Learning through Crossword Puzzle-Based

Teaching mathematics, in elementary school requires Creative strategies that go beyond traditional lecture method. Creative strategies that go beyond traditional lecture method. Young learner often struggles with abstract concepts, making it important to design lessons that are interactive, engaging and student centered. One effective approach is to combine structure teaching model with playful learning Activities that increase motivation and. Activities that increase motivation and. Participation. Games and puzzles can help student development. Solving skills. While making learner more enjoyable. Integrating this element within a well-planned framework support deeper conceptual understanding. The quantum teaching model. Offers such a framework by emphasizing experiential learning, reflection, and celebration by adopting this model. To include game- based technique, teacher can create a classroom environment that encourage curiosity, collaboration and active environment.

Alfarisi, Prihandini, and Adawiyah (2018) Investigated the use of quantum teaching model. Integrated with crossword puzzles technique and improving student learning outcome and mathematics Specifically in the topic of integers conducted as a classroom action research project. The study was implemented across two cycles in a third-grade class of SDN 01 with pakis 01 with 40 students. Using the TANDUR Framework. The instructional design. Engage student through experiential learning and. Gamified content crossword puzzle were used to reinforce conceptual understanding and increased motivation The results showed a marked improvement in both student learning outcome and classroom activities student achievement. Rose from 75% to 83.3%. Rose from 75% to 83.3%. An actively level improved from 70.27% to 83.55% between two cycles. the Study concluded that integrating playful and problem-solving elements such as crossword puzzle within the quantum teaching method framework can enhance student motivation, participation, and comprehension, making abstract mathematical concepts more accessible and enjoyable.

2.2.8 Effect of Quantum Learning Model Assisted by Animation Media on PPKn Learning Outcomes

Improving learning Outcome and subject like PPkn requires teaching model that actively engage students and. Make abstract concept more understandable. Visual media settings. and amination can survive a powerful tool to capture student and trust and support meaningful learning. When combined with structure instructional approaches. That media can enhance both cognitive and affective domain of learning. The quantum learning model is designed to create interactive student-centered experience that encourage participation and reflection and enjoyment. Integrating animation with this framework offer opportunity to simplify complex idea and maintain student motivations such as combination supports differentiated learning by appealing to diverse learning style and need overall leveraging technology alongside established teaching model can significantly strengthen. Classroom practice and student achievement.

Albela, Sabrina, Sari, and Utomo (2024) conducted Literature based study to explore the effect of quantum learning model assisted by the animation media on the PPKn learning outcome of grade V. Students The research synthesized finding from the various study and found the consistent improvement and student learning outcome across subjects when QTM was integrated with engaging visual media. The study reported that average learning outcome was from 57.30 before implementation to 78.72 after incorporating quantum learning with animation. The combined approach increased motivation, content retention, and conceptual understanding. The visual stimulation provided by animation helped Bridge abstract civic concept, making them more accessible and engaging from student. These outcomes suggest that integrating animation media with QM enhance both cognitive and affective learning domain. This review supports the utility of QTM across disciplines and confirms the adaptability of the model when paired with digital media, especially in fostering students centered. interactive and enjoyable learning environment.

2.2.9 Problem-Based Quantum Learning Model

Modern development of high order thinking Skills such as problem solving, reflection and self-regulation. requires instructional models that combine structured pedagogical strategies with opportunities for independent learning and critical engagement. Problem based learning is one such approach that fosters active inquiry and collaborative problem solving when integrated with model like quantum teaching at create a powerful learning environment that promote both cognitive engagement and social interaction. This hybrid approach can especially useful and developing the skills required for discipline that relay and reasoning and critical thinking. And ability to apply knowledge and practical contexts this makes such models highly relevant for improving instructional practices across various content area including mathematics

.Ökmen, Şahin, and Kılıç (2023) Proposed a hybrid educational model. Problem Based quantum learning Combining the step of problem-based learning with the quantum teaching method Conducted with English language teaching Major the study employed A pretest and posttest experimental design to examine the effect of PQL on self-efficiency, cooperative learning, and metacognitive thinking skills. Although the quantitative results showed modest gain and attitude toward collaborative learning. And no significant difference in metacognitive Thinking skills, qualitative data suggests. Improvement and problem solving, reflection and decision-making abilities The PBQL model Encourage individual and group learning, increase motivation, and help preservice teacher develop classroom management, instructional planning, and engagement strategies. It was noted that conceptualized problem situations, student ownership of learning, and interdisciplinary connection. Contributed to enhance learning outcome while the study did not directly measure mathematical reasoning It emphasized on high level thinking, problem solving and metacognitive engagement aligns strongly with competency central to mathematical reasoning there for PBL is relevant for informing effective teaching strategies in math education.

2.2.10 Quantum Learning Combined with Make-a-Match Method

Strengthening Students mathematical understanding in elementary school requires teaching approaches that balance structure with active. engaging method traditional instruction often fail to sustain interest or develop deeper conceptual comprehension combining structured frameworks like quantum learning with interactive techniques can create a more dynamics learning environment such integration supports motivation participation, and the retention of challenging concepts game-based strategies encourage students interaction and make abstracts ideas more accessible by blending these approaches educators can tailor instruction to diverse learning needs and promote meaningful lasting understanding. This combined methodology is especially valuable. For teaching complex topics such as friction in ways that are enjoyable and effective

Rusnilawati et al. (2020) conducted A quasi experimental study to examine the impact of integrating the quantum learning model with make a match method on the cognitive Abilities are grade for elementary student and mathematics. Experimental group was taught using this combined approach, while the control group was used traditional cooperative learning model. Cognitive ability was assessed through pre, and posttests and the results showed a significant improvement in the experimental group ($Z=2.46$, $p < 0.05$), indicating that the intervention had na stronger effect on students' ability to understand and process mathematical concepts such as addition and subtraction of unlike fractions.

The study emphasized the benefits of quantum learning framework particularly its emphasis on engagement experience and celebration and the make and match technique which enhance interaction and conceptual retention through game like matching activities. Students in the experimental group reported higher motivation better engagement and deeper understanding of mathematical content. The findings suggest that combining quantum learning with active game-based strategies can substantially enhance cognitive development and support mathematical reasoning skill in elementary education.

2.2.11 Improving Social Studies Learning Outcomes through Quantum Teaching

Enhancing learning outcome in elementary education often requires teaching models That foster not only cognitive skill, but also emotional engagement and collaboration. An effective instruction approach should create a supportive environment. Where students feel confident in effectively and innovatively in their learning process. Learning process Quantum teaching with its emphasis on experiential learning and structure phase offer such a framework by promoting Participant and celebrating process This model can transform classroom dynamic and encourage deeper understanding These principles are applicable across various subjects. Includes social study and mathematics, where student engagement is critical to mastery Implementing strategy That combine cognitive and effective domains supports comprehensive development Such model increasingly recognized for their role in improving both academic achievement and student. achievement and student. Motivation in early education.

Syamsuriyanti and Amalia (2022) Conducted a classroom action research study on the application of quantum teaching murder to improve learning outcome in social study among 4th grade student at SD inpres Bontomanai makassar. The study was implemented in two cycles. During the first cycle, only 51% of the student achieved the minimum learning mastery with an average score of 72. However, significant improvement was observed in the second cycle Where 87% of students reach mastery with an increased average score of 86. this study demonstrated how the implementation of quantum teaching model. Through its TANDUR Framework Grow experience named, demonstrate, repeat, celebrate promoted in emotionally engaging, collaborative and supportive learning environment Observational data indicated improvements in classroom, participant, group collaboration, and student enthusiasm in particular students exhibited stronger motivation timely attendance willingness to participate in discussions and increased confidence in sharing their ideas. While the study focused on social studies the findings are directly applicable to mathematics education. The same cognitive engagement emotional involvement and structured learning process central to QTM can be leveraged to improve mathematical reasoning. This research adds to growing body of evidence that QTM is a flexible and effective model for enhancing both academic outcomes and students' engagement across various subjects in elementary education.

2.2.12 Improving Science Learning Activities through Quantum Learning

Improving student engagement and participation is a critical factor in enhancing learning outcome across subject activate. Student centered approaches that encourage collaboration, inquiry and positive emotional experience help transform traditional classroom into dynamic learning environment. Quantum learning provides a structured framework that support these elements through its cyclical process of Growth, experience, reflection and celebration. By fostering meaningful interaction and hand on activities this model promotes deeper understanding and confidence among students Set approaches are valuable not only in science education. Such approaches are valuable not only in science education. But also, in developing skills like Mathematical reasoning which benefit for experiential and emotional supportive teaching Implementing these strategies can lead to significant improvement in both student motivation and academic achievement. The adaptability of quantum teaching makes it a promising tool for diverse educational contexts.

Afidin et al. (2022) implemented the quantum learning model to enhance science learning activity in grade 6 elementary student initially science learning. Activities were low with only 40% student participant. After implementing the quantum teaching cycle including guru. After implementing the quantum teaching cycle including grow experiences name, demonstrate, repeat and celebrate students' activity rose dramatically to 90%. The study revealed that teacher activity also improved from 50% to 90% as they learned teaching practice with the quantum Learning framework. Key improvement student collaboration, critical observation, group discussion, and increased confidence in classroom participation. Student showed enthusiasm During its experiment and demonstrated meaningful learning engagement despite Minor challenges such as the need for through preparation and grouped reformation. The study concluded that quantum teaching method effectively transformed. The study concluded that quantum teaching method effectively transforms passive learning environment into active student-centered classroom Although the focus was on science, the findings underscore the value of experiential, inquiry based and emotionally positive learning environment. Which are also essential for cultivating mathematical reasoning. as such quantum teaching methods structured student centered approach can be adapted to math's education for similar gain and reasoning and engagement.

2.2.13 Improving Mathematical Concept Mastery with HOTS-Speed Test Integrated Quantum Learning

Enhancing mathematical concept mastery Requires Instructional models that actively promote higher order thinking and real-world connection. Integrating evaluative Tools that challenge student analytical and critical skills can deepen understanding and increase motivation. Quantum learning when combined with targeted assessment. Like HOTS- speed tests for a comprehensive approach to Foster both cognitive development and engagement. Such integration support collaborative learning, reflective thinking, and meaningful feedback. Key component and strengthening Mathematical reasoning. By creating a learning environment that value curiosity and Participation educator can improve not only academic outcome but also student confidence and enthusiasm This approach is particularly Relevant for secondary education were Complex problem-solving Skills become essential. Applying these strategies lead to more effective and stimulating mathematics instruction.

Mahendra (2022) conducted classroom action research study to access whether integrating the quantum learning model with HOTS- speed test Could improve mathematic learning outcome Among student of class XI jasa boga 1 at SMK pariwisata harapan denpasar. The study involved two cycle and reveal a significant Increase in student performance from an average score of 60.25 in the pre observation phase, to 77.50 in the second cycle. With MLO improvement rates of 7.88% and 19.23%. Across the cycles. The finding highlighted key pedagogical interventions such as using real life context, video and picture to relate mathematical concept to student experience. The HOTS Speed test provided an evaluative component encouraging I order thinking improvement were Noted in student participation. Conceptual understanding and confidence. The teacher use of collaborative grouping, feedback strategies and reflective questioning reinforce deeper engagement. The study affirms that the HOTS Integrated quantum learning model is highly effective in enhancing not just academic performance. But also, student motivation, curiosity and critical thinking ability and mathematics classroom.

2.2.14 Enhancing Elementary Mathematics through Quantum Learning

Elementary students understanding of foundational mathematical concepts requires engaging and context rich instructional approaches. Teaching method that encouraged inquiry collaboration and practical application can enhance both comprehension and retention structure framework like Quantum Learning support active participation and provide opportunity for students to explore Concepts Through meaningful experiences. Incorporating interactive tools and real-world example help make its abstract ideas tangible and relatable. Such approaches not only improve student performance but also foster enthusiasm and confidence and learning mathematics. And confidence and learning mathematics. Teacher effectiveness is similarly enhanced When instructional delivery aligns with the Student Center strategies. Overall, this holistic focus promotes people learning and motivation in early mathematics education Santoso, Wibowo, Raharja, and Bafirman (2024) examined the application of quantum learning to enhance elementary student's ability to calculate the area of a rectangle conducted through classroom action Research the study includes pre cycle cycle 1 and cycle two phase it. The study includes pre cycles cycle 1 and cycle 2 phases. at Jayapura Adventist Elementary School. The results demonstrate that student performance improves significantly from appeals line average below standard to full mystery 100% and identifying styles, angle and dimension of anger.

The results demonstrate that student performance improves significantly from baseline average below standard to full mystery 100% in identifying sides, angle and dimension of rectangles and 94.12% accuracy and calculating Area using Standard and nonstandard methods. The learning process applied the TANDUR Model and was supplemented with observation Interviews, written assignment, and documentation. key gains include increased student enthusiasm inquiry behavior, participation and presentation skill. Teacher effectiveness also improved Reaching a 95% success rate in instructional delivery. The research highlighted the important of real-world contexts interactive tools and group collaboration and enhancing student understanding and retention of mathematical concept. The study concluded that. Quantum learning not only strengthen mathematical concept mystery but also boost student Motivation and teacher proficiency.

2.2.15 Enhancing Science Learning Quality through Scientific Approach and Quantum Teaching

Improving the quality of science learning in elementary education requires teaching model that actively engages student and foster deep understanding of scientific concept. Approaches that integrate inquiry-based method with structured framework can promote meaningful learning experiences Combining the scientific approach with muddle like quantum teaching method offer a systematic Way to encourage observation, questioning, experimentation and reflection. Such integration support not only cognitive development but also emotional engagement and motivation. Such integration support not only cognitive development but also emotional engagement and motivation. By incorporating collaborative activities and strategic teacher guidance, these models create dynamic classroom that nurture curiosity and critical thinking. The holistic approach is Particularly effective in helping student grasp Complex scientific idea and processes Enhancing both teacher skill and student participation is essential for achieving sustained improvement and learning outcome.

Putri et al. (2024) conducted classroom action research in elementary school is bandung Focusing on integrating the scientific approach with the quantum teaching model to enhance science learning quality. The study, based on Kemmis and McTaggarts model was implemented in two cycle and exists through teachers' skills, student activities and learning.

In the first cycle, student engagement increased with 79% Student reporting positive emotion toward learning. The average learning outcomes. Score was 52.5% in the second cycle, 87.5% of student showed positive engagement Learning outcome rose to 69.25%. The implementation includes structure steps observation, questioning, experimenting, associating and communicating aligned with the TANDUR framework. Students participate in role play, game group discussion, and individual assessment. Teachers employed, Media Strategic. Questioning and reflective practices to sustain motivation and curiosity. The result indicated improvement in student understanding of concept. Like energy flow, food chain and food webs. Especially among those with initial low cognitive performance. The study concluded that the scientific approach enhanced by quantum teaching. Foster meaningful engagement deepens scientific reasoning and enhancing learning quality.

2.2.16 Strategies to Improve Critical Thinking Skills through Problem-Based Quantum Learning Model

Developing critical thinking skill is a fundamental goal and the elementary education. Especially as a student encounter increasingly complex problem, effective instruction strategy needs to engage learner active problem solving and reflecting thinking within meaningful contexts. Integrating problem-based learning with structured teaching models provide opportunity to nurture these high art thinking skills. The quantum teaching framework with it emphasizes on experiential learning and student reflection supports such integration effectively. By encouraging learners to analyze, evaluate, and draw conclusion. These approaches build essential competencies for mathematical reasoning and real-life decision making. understanding students thinking process through model like FRISC Further enhances targeted interventions Together, these strategies contribute to creating classroom environment conducive to critical thinking development. Kusuma, Gunarhadi, and Riyadi (2018) conducted a descriptive statistical study to evaluate the critical thinking ability of 156. Grade student across primary school in Karanganyar Sub- district. The study applied a problem-based quantum learning model and accessed 5 indicators of critical thinking, interpretation, analysis, evolution, explanation and conclusion. The results showed that students scored high in interpretation and conclusion, medium, instance planation and evolution, and varied analysis depending on school. The results showed that students scored high in interpretation and conclusion, medium, in explanation and evolution, and varied in analysis depending on school accreditation. The study underscored the important of problem solving is a strategy to develop critical thinking with finding indicating that experiential and contextual learning. That is facilitated by the quantum teaching framework. enhanced student engagement and reflection. The FRISCO model (Focus Reason. Inference Situation, Clarity Overview) Was used to interpret Student through processes. This research provides A valuable insight into how the integration of quantum teaching method with problem-based learning can enhance critical thinking, a core component of mathematical reasoning skill especially in real world contexts.

2.2.17 Mathematical Reasoning Abilities in Gifted Students through Problem- and Project-Based Learning

Student often require instructional models That challenge their advanced reasoning skill and fostered deep conceptual understanding. Approaches that emphasize problem solving. Project based activities. And inquiry can provide meaningful context for developing these abilities. Such model encourages collaboration, critical thinking and application of the knowledge to real world situation. By engaging actively These strategies help maximize Cognitive growth and motivation. Comparing different instructional model allow educator to identify the most effective approach for nurturing. Mathematical reasoning and gifted. Population. Integrating these insights with framework like quantum teaching can further enhance instructional quality. This combination support tolerated learning experiences that promote both academic achievement and higher order thinking.

Abidin et al. (2021) Investigated the mathematical reasoning ability of Gifted elementary school students using three instructional model. Problem based learning, project-based learning and inquiry learning. Employing a quantitative randomized pretest posttest control group design the study involved 72 gifted 5th grade students. The result indicated that PBL group showed the highest gain in reasoning ability M =79. 30 followed By PJBL (M=69.87), and inquiry learning (M=57.15) Statical analysis via ANOVA confirmed significant difference among the group Favoring PBL as the most effective model.

The findings support the effectiveness of PBL in promoting high order thinking, reasoning by engaging studying, and contextualize problem solving and peer collaboration. PBL Also positively influence reasoning through literacy. Based project that encourage integration of mathematical concepts with real life scenario. Inquiry learning, while effective and the concept discovery, showed limited result in fostering deeper reasoning. The study underscores the importance of instructional model. That promote active engagement and real-world relevance, both of which align with the principle of quantum teaching.

2.2.18 Transforming Science Learning Through Quantum Teaching

Transforming learning environment to foster critical thinking and inquiry is essential in elementary education Teaching model that emphasized active participation, conceptual connection, and flexible thinking in significantly enhance student cognitive development. Quantum teaching exemplifies such as stop model by drawing on principles that encourage multiple prospective and nonlinear learning pathways. These elements support students and exploring complex idea and a developing reasoning skill necessary for both science and mathematics. By promoting curiosity creativity and metacognition.

Student centered approach like quantum teaching help build foundational competency across STEM subject. Understanding how these pedagogies affect engagement and achievement can inform more effective instructional practices. Consequently, integrating such model hold promises for cultivating deep reasoning and young learner. Siahaan, Marson, and Forsyth (2022) explore the transformative effect of quantum teaching in primary school science education.

Emphasizing it holistic, student centered and inquiry-based foundations. while their study primarily addressed science learning pedagogical implication of quantum teaching directly align with the cognitive process required for mathematical reasoning. Such is a critical thinking Problem solving and concept integration. The author described quantum teaching is a method that reimagines the classroom into environment of dynamic active learning inspired by principle of quantum physics such as Interconnectedness, multiple prospective and nonlinear learning paths. These principles translate into a flexible teaching model that encourages students to explore complex idea, draw conceptual connection and approach from diverse angles skills crucial to developing Mathematical reasoning.

Empirical finding from their quasi-experimental study revealed the student. engaged in quantum teaching. Demonstrate enhance engagement, curiosity, creativity and critical inquiry. This method also supports differentiated instruction, metacognition, and interdisciplinary thinking. These features are Essential and mathematical reasoning Particularly For helping students justify, generalize and construct logical argument with working with abstract math's problem. Particularly, quantum teaching was shown to improve. Classroom dynamic curriculum design, assessment method and student motivation. Teacher noted increasingly participation and confidence among students, while assessment data indicate improvement and learning achievement. These outcomes suggest that quantum teaching can survive as a valuable model for math's educator aiming to cultivate deep reasoning skills.

Although the study was based and science education and its finding a affirm the broader Applicability of quantum teaching across STEM disciplines. The student-centered inquiry-based Nature of QT make it highly relevant for elementary mathematics education where foundational reasoning skills are developed. Thus, the work by Siahaan et al. (2022) support the Integration of quantum teaching is a powerful method for improving both science and mathematical cognition and young learner.

2.2.19 Enhancing Mathematics Learning Outcomes Using Quantum Teaching

Improving mathematical learning outcome requires instructional model that engages student both emotionally and cognitively. Structured approach that. Connect real life contacts with active participation help foster deeper understanding and motivation. The quantum teaching model, particularly Through its TANDUR Framework offer a comprehensive cycle that encourage growth, experience, reflection and celebration and learning. By guiding students through meaningful phase of engagement and reinforcement This model address Common challenges such as student anxiety and disengagement. Collaborative strategy and support material further enhance learning effectiveness. These elements. These elements. Create a positive and dynamic environment conducive to mastering complexing mathematical concept. Such models are critical for improving achievement and participation in mathematics education. Arum and Amir (2019) Conducted a classroom action search to evaluate the effectiveness of quantum teaching model. Specifically, the TANDUR Teamwork and improving mathematical learning outcome among grade eight student at SMP Negeri 1 Maros. Implemented there are two cycle the study Integrating student Worksheet with discussion Based strategy to foster greater student engagement and understanding of mathematical concept. The TANDUR cycle Tumbuhkan (Grow), Alami (Experience), Namai (Label), Demonstrasikan (Demonstrate), Ulangi (Repeat), and Rayakan (Celebrate) Was used to structure the learning process. In the guru and experience stages, student entrust was cultivated Through relatable real-life connection and active participation. That demonstrate and repeat. Please encourage knowledge, articulation and reinforcement. While the celebrate face foster motivation and positive reinforcement. Quantitative data from the two cycles showed an improvement in student achievement. The percentage of student meeting the minimum Learning Mastery increase from 60.53% in Cycle 1 means score = 66.84 to 73.68 % In cycle 2 means score = 70.39. Similarly, student actively level rose from 61.44% to 71.44%. And teacher performance score improved from 66.67% to 79.17%. Qualitative finding emphasized increased student participation and collaboration and confidence. Student demonstrate A willingness to engage in problem solving, discussion and presenting their work. The study concluded that the quantum teaching model, especially when support with LKS and collaborative learning, effectively enhance student cognitive engagement and motivation and learning outcome in mathematics. These findings support the broader argument that the QTM foster meaningful students. Students centered learning environment and is especially effective in challenging subject like mathematics where student anxiety and disengagement are common.

2.2.20 The Effect of Quantum Teaching and Motivation on Student Achievement

Student motivation plays a crucial role in the academic achievement across subject, especially science and mathematics. Teaching approaches that actively engages learner emotionally and cognitively tend to produce better outcome. Quantum teaching embodies these principles by creating dynamic, interactive and student-centered learning environment. By incorporating strategies such as ice breaking activity, motivational slogans and flexible communication, educator can foster enthusiasm and participation. These elements help reduce learning activity and promote sustained engagement. Understanding how Motivation interact with teaching method is essential for designing effective instruction combining motivational support with. structured teaching framework can thus significantly enhance student achievement.

Zaroha, Firman, and Desyandri (2019) examined the impact of quantum teaching and student motivation on science achievement among fifth grade students in Padang Barat. Using a quasi- experiment 2x2 factorial design. The study revealed that student through quantum teaching strategy achieves significantly higher learning outcome than those taught through conventional method. The effect was even more pronounced among students with high intrinsic motivation, but notably, even students with low motivation showed improved performance with thought using quantum teaching. the study underscored the pedagogical value of emotionally engaging students. Centered and interactive classroom environment. Hallmarks of each quantum teaching it also emphasizes the role of instructional design that incorporates slogans Icebreaking activity, Inflexible communication, Faster and engaging learning atmosphere. These findings support that integration of quantum teaching in primary mathematics' and science instruction as it not only enhance academics performance but also cultivates student motivation and classrooms enthusiasm.

2.2.21 Quantum Teaching and 21st-Century Skills Development

Developing 21st century skills such as collaboration, communication and critical thinking is essential for preparing Student to succeed in complex and dynamic environment.

Instructional model that promotes active engagement and meaningful connection between content and real-life situation are particularly affecting and fostering. These competencies. Quantum teaching with its structured TANDUR framework offers a systematic approach to nurture both cognitive and social skills by encouraging teamwork responsibilities sharing this model helps Students develop the collaborative thinking vital for problem solving and reasoning such skill Are integral not only in social contexts but also in mastering mathematical concepts integrating these strategies into mathematics education supports comprehensive learning and the development of deeper reasoning abilities. Consequently, approaches like quantum teaching align well with modern educational goals.

Nahar et al. (2022) explored the impact of the quantum teaching model on elementary students' collaboration thinking skill with in context of Islamic religious education their quasi-experimental study employed a pretest posttest control group design with 55 students and found statistically significant improvement in collaboration skills among the experimental group exposed to the TANDUR framework (Grow, Experience, Name, Demonstrate, Repeat, Celebrate). This result was supported by independent t test and descriptive analyses that highlighted increased student participant teamwork and responsibility sharing. Although their study was conducted in the domain of religious education the finding supports the general applicability of the quantum teaching model for enhancing 21st century competencies such is collaboration communication and critical thinking who are also central to mathematical reasoning

The TANDUR syntax fosters deeper engagement and encourage student to make meaningful connections between abstract contents and real-life contexts this aligns with the goals of mathematics reasoning instruction which seeks to cultivate students' ability to analyze justify and apply mathematical thinking to problem solving. The improvement in students' collaboration thinking that reinforce the effectiveness of quantum teaching not only in increasing academic outcomes but also in supporting the social and cognitive processes involved in reasoning therefore this study provides additional justification for adopting the quantum teaching method in mathematics classrooms aiming to develop reasoning skills.

2.2.22 Students' Mathematical Reasoning Skills in Solving Non-Routine Problems

Developing strong mathematical reasoning skill is essential for student to successfully tackle complex non routine problem. That required more than professional knowledge. Many students struggle not only with selecting appropriate strategy but also in articulating and justifying the reasoning process This highlights the important of explicit teaching method that emphasize problem solving, critical thinking, and metacognition

Ersoy and Bal-İncebacak (2017) conducted a qualitative case study to examine the mathematical reasoning skills of 7th grade students in turkey utilizing Marzano's (2000) scoring rubric to assess students responses to non- routine mathematical problem the study involved 95 students and revealed that only a small percentage of participants could select and implement appropriate problem solving strategies effectively although some students chose the correct approach they struggles to articulate their reasoning or complete the solution process their answers the authors emphasized the significance of providing students with opportunities to engage with non-routine problems to develop their reasoning problem solving and metacognitive abilities. They also highlighted the need for explicit instruction and curriculum integration of reasoning-based learning experiences to enhance students mathematical thinking this research support the argument that exposure to varied problem types and targeted pedagogical strategies is critical for fostering high order mathematical reasoning skill at the middle school level.

2.2.23 Promoting Mathematical Reasoning through Problem-Based Learning

Mathematical reasoning skill is very important in early school level Providing learner with a varied problem tied to unity to engage. And learner with varied problem types and opportunity to engage deeply with challenging task foster these competencies integrating reasoning focused instruction and the curriculum is vital for improving studying ability to generalize and logically support their solution. Middle school is a critical period for strengthening such high orders. Skills which survive is the foundation of advanced mathematics learning. Skills which survive is the foundation of advanced mathematics learning. Napitupulu (2017) investigated the development of mathematical reasoning skills among upper secondary students in Indonesia through a problem-based learning framework. The study employed the Four-D model to design instructional material and use holistic rubric to Assess MRS based on 4 indicators. Drawing logically conclusions explaining model and relationship, making conjectures and proofs, using pattern relationships to generalize findings show that student particularly struggle with using pattern to analyze situation and generalize. However, student demonstrates improved performance and making congestion improve when supported by scaffolded instruction and task, closely resembling classroom example. However, student demonstrates improved performance and making congestion improve when supported by scaffolded instruction and task, closely resembling classroom example. The study concluded that mathematical reasoning skill can be enhanced through intensive teacher guidance varied problem exposure and learning experiences that encourage self-directed exploration and reasoning these finding support the integration of PBL and strategic scaffolding in mathematics classrooms to promote higher order thinking and conceptual understanding among secondary students

2.2.24 Effect of Quantum Teaching Method in Secondary English Education

Improving language skills such as reading comprehension required instructional method that engage learners actively and connect real world context approaches fostering student participation, motivation and confidence tend to produce better academic outcome. The quantum teaching Method offer a structured yet flexible framework that promote experiential learning. Reinforcement in celebration of progress. By creating a student-Centered environment This method encourages meaningful interaction with content and support deeper understanding. Its stages guide learner through engagement conceptual labeling demonstration and review making complex texts more accessible such pedagogical strategies are particularly valuable in enhancing comprehension skills in secondary education. Applying these principles to language learning aligns well with broader goals of improving critical thinking and academic achievement Dina (2024) conducted a quasi-experimental study titled the influence of quantum teaching method towards students reading comprehension at the eleventh grade in one in one of senior high schools in Sekampung Udik East Lampung in the Academic Year 2023/2024." The research was carried out at SMA muhammadiyah 1 sekampung udik and involved two classes comprising 54 students. The purpose of the study was to examine whether the application of the quantum teaching method significantly affects students reading comprehension specifically in understanding report texts. The participants were divided into an experiemntal group (XI MIPA 2), which receive instruction using quantum teaching method and a control group (XI IPS), which was taught through contextual teaching and learning. both groups took a pretest and posttest to measure their reading comprehension levels the results indicated that the experimental group outperformed the control group the experimental group mean score increased from 56.18 pretest to 80.56 posttest whereas the control group mean improved only slightly from 50.28 to 53.01 statistical analysis using the mean and t-test showed a significant difference in the post test results between the two groups (Asymp. Sig. (2-tailed) = 0.000 < 0.05), indicating a positive influence of the quantum teaching method.

The quantum teaching method as implemented in the study followed a structured model consisting of six stages Enroll Experience Label Demonstrate Review and Celebrate these stages were designed to create an engaging and student- centered learning environment allowing students to actively participate in the learning process relate the content to real life experience and reinforce their understanding through repetition and celebration of achievement In conclusion, the study found that the quantum teaching method significantly enhanced students reading comprehension skill in report texts the approach was noted for increasing student motivation participation and confidence suggesting its effectiveness in improving language learning outcome.

2.2.25 Improving Elementary Social Studies Learning Outcomes Through the Quantum Teaching Model

Improving student engagement and comprehension the social study is a common challenge in elementary education. Especially when traditional instruction relies heavily on lecture-based method. Active in brain-based learning approach are needed to create more stimulating effective learning environment. The quantum teaching model, which emphasizes whole brain development and students centered strategies Offer a promoting solution by incorporating experiential activity, reflection and collaborative. Learning it fosters motivation confidence and deeper understanding such model can transform passive classrooms into dynamic spaces that promote both academics achievement and emotional involvement implementing these strategies helps address student boredom and supports mastery of complex social studies concepts this approach is increasingly recognized for its ability to improve learning outcome across diverse subjects.

Fadhilah, Eritia, and Yulia (2022) conducted a classroom action research study to improve students learning outcomes in social studies for Grade IV at SDN 13 padang Gelanggang using the quantum teaching model this research was motivated by observed challenge in traditional social studies instruction which often relied heavily on teacher centered lectures leading to student boredom low engagement and poor comprehension of complex material.

The study involved 20 students (12 boys and 8 girls) and followed a two- cycle classroom Action Research approach with both qualitative and quantitively methods each cycle included planning implementation observation and reflection the quantum teaching model as explained by deporter was implemented to create a more engaging and brain-based learning environment that fosters both left and right brain development.

Findings indicated a notable improvement in both teacher performance and student learning outcomes teacher activity scores increased from 75 to 89.06 while students average scores rose from 68.81 to 84.36 moving from a moderate to a very good category qualitatively students showed greater motivation confidence and active participation during learning sessions. The study concluded that the quantum teaching model effectively enhanced students understanding engagement and academic performance in social studies and is recommended for broader implementation in similar classroom contexts.

2.2.26 Effects of Quantum Learning on Nursing Education

Effective learning in professional fields like nursing requires instructional approaches that foster active engagement motivations and long term retention traditional lecture based methods often fail to fully address the dynamic and complex nature of clinical decision making quantum learning offers a multisensory student centered framework that integrates experiential activities with motivational strategies to enhance learning outcome by tailoring instruction to individual learning styles and creating interactive environments this model supports deeper understanding and practical skill development such approaches are critical in preparing student for real world challenges where both knowledge and retention are essential. Evaluating the impact of quantum learning and health education help expand its applicability beyond general a classroom.

Khozaei et al. (2022) conducted a quasi-experimental study to compare the effectiveness of the quantum learning methodology with conventional teaching methods on nursing students learning achievement motivation and retention during a critical care nursing course in Iran recognizing the increasing demand for creative dynamic thinking and clinical decision making in nursing education the study aimed to determine whether a more engaging student centered approach could better prepare students for real world challenges in health care the sample consisted 42 sixth semester nursing from the Mashhad University of Medical Sciences, divided into two groups an experimental group taught using the quantum learning model and a control group taught via traditional lecture methods the

QLM implemented through the six phase EELDRC framework the learning environment was carefully structured with music visuals and motivational cues to enhance engagement students individual learning styles were identified using Kolb's learning styles inventory and incorporated into lesson planning key findings are the learning achievement score in the QLM group (m=16.84 SD = 2.28 were significantly higher than those in the (M = 15.16, SD = 2.41; $p < 0.045$). retention scores one-month post intervention were also significantly higher in the QLM group (M = 13.25) compared to the control group (M = 11.71; p = 0.005) although pretest and posttest motivation scores in the QTM group significantly improved (p 0.010) there was not significant difference in motivation scores when comparing between the two-group post intervention (p = 0.480). the study concluded that quantum learning environments which are rich in interactivity motivation and multi-sensory engagement can significantly enhance both short term learning and long-term learning retention while the increase in motivation was more pronounced with in the QLM group over time the difference between groups was not statistically significant.

2.2.27 The Influence of Quantum Teaching on Elementary Science Learning Outcomes

Improving student engagement and achievement in elementary science remains a critical challenges for educators particularly when traditional lecture-based methods results in passive learning and low motivation teaching approaches that actively involve students and connect lessons to real world experience tend to produced better outcomes the quantum teaching model structured around the TANDUR framework offers a comprehensive method to create stimulating student centered learning environments. By emphasizing experiential learning reinforcement and celebration it promotes deeper understanding and retention such frameworks are particularly effective in fostering enthusiasm and conceptual mastery in young learner’s research exploring the impact of quantum teaching in science education helps validate its potential to transform classroom dynamics. Larasati and Baadilla (2023) conducted a quantitative experimental study to evaluate the impact of the quantum teaching model on the science learning outcomes of fifth grade students at SDN Balekambang 01 Pagi, Jakarta. The researcher identified that traditional method such as lecture-based instruction led to student disengagement and low performance in science subject this study was designed to determine whether quantum teaching could foster a more engaging learning environment and lead to improved academic achievement.

The study employed a true experimental design with a pretest posttest control group approach a total of 64 fifth grade students were randomly divided into two equal group 32 students in the experimental group (taught using the quantum teaching model) and 32 in the control group (taught using conventional methods) the data collect process included validated and reliable multiple-choice test administered before and after the intervention. The quantum teaching model was implemented following the TANDUR framework; Tumbuhkan (Grow) stimulating interest and motivation Alami (Experience) providing direct learning experiences Namai (Name) introducing keys concepts Demonstrasikan (Demonstrate): allowing student to show their understanding, Ulangi (Repeat) reinforcing through repetition Rayakan (Celebrate) appreciating students' achievements

Key findings include the experimental groups posttest average was 78.00 significantly higher than the control groups average of 60.00 with a mean improvement of 34.37 versus 18.08 respectively. Statistical analysis using in independent samples t-test yielded a p- value of 0.039 indicating a significant difference between the two groups in favor of the quantum teaching model. The results also confirmed that the learning environment was more engaging and student centered under the quantum teaching model encouraging active participation motivation and comprehension. The authors concluded that the quantum teaching model significantly improves science learning outcomes by making lessons more interactive contextual and enjoyable. They advocate its adoption in elementary science education to replace less engaging teacher centered method.

2.2.28 Improving Collaborative Thinking Skills through the Implementation of the Quantum Teaching Model

Developing collaboration skills is crucial for preparing students to navigate the demands of the 21st century were teamwork and communication are highly valued educational models that actively engage students and promote cooperative learning have shown promise in enhancing these skills quantum teaching with its structured TANDUR framework provides s systematic approach to foster collaborative thinking through experiential activities reflection and shared celebration of achievements by encouraging active participation and role sharing this model supports social and cognitive growth. Integrating such approaches into classroom practice aligns with global educational goals emphasizing holistic development the effectiveness of quantum into classroom practice aligns with global educational goals emphasizing holistic development the effectiveness of quantum teaching in promoting collaboration warrants further exploration especially in value based and religious education contexts.

Nahar, et al. (2022) aimed to examine the effectiveness of the quantum teaching model in enhancing collaboration thinking skills among elementary students in Islamic religious education classes conducted at integrated Islamic elementary school al-musabbihin medan the quasi-experimental study involved 55 students divided into experimental and control groups. The experimental group received instruction through the quantum teaching model following the TANDUR framework (Grow Experience Name Demonstrate Repeat Celebrate) while the control group used conventional group discussion method. Pretests and posttest alongside questionnaires and interviews were used to measure outcomes. Results showed a significant improvement in the experimental group collaborative skills with a post test score of 81.50 compared to 75.00 in the pretest. Five key collaboration indicators effective work compromise role sharing productivity and evaluation improved notably statistical analysis ($p = 0.007$) confirmed the model's effectiveness the study concludes that the quantum teaching model not only enhances students' collaboration and engagement but also supports the development of essential 21st century skills and aligns with UNESCOs educational pillars. It recommends teacher training and supportive policy implementation for wider application of the model in value-based education contexts.

2.2.29 Effectiveness of the Quantum Teaching Approach in Enhancing Science Learning Activities Among Elementary Students

Active student participation is a key factor in improving learning outcomes particularly in subject like science that benefit from hand on experience and inquiry. traditional teaching method often struggles to maintain high levels of student's engagement leading to less effective learning. The quantum teaching approach based on the structured TANDUR framework offers a comprehensive strategy to create interactive and motivating classroom environments by incorporating phases that stimulate students' involvement. The model emphasis on emotional and cognitive engagement aligns with modern pedagogical goals of fostering meaningful learning. Evaluating its effectiveness in elementary science classrooms helps validate its broader applicability.

The study by Nurmalisa, Kune, and Ristiana (2022) investigated the impact of the quantum teaching learning approach on science learning activities ammong garde V students at Mandai state elementary school in Makassar. Utilizing a quasi- Experimental nonequivalent control group design 62 students were divided into experimental and control groups. The experimental group was taught using the quantum teaching model, while the control group received conventional instruction. Observation sheets were used to assess student activities such as viewing speaking listening writing and mental engagement. Results revealed that students in the experimental group demonstrated a significantly high level of engagement with an average activity score of 81% categorized as very active compared to control 72% in the control group categorized as active the study concluded that quantum teaching approach characterized by its structured TANDUR stages effectively enhance students' science learning activities by fostering a more interactive enjoyable and meaningful learning environment.

2.2.30 Students' Mathematical Reasoning Behavior

Understanding how students demonstrate mathematical reasoning is fundamental to improving teaching strategies that foster deeper cognitive engagement. reasoning behavior ranges from basic memorization to sophisticated creative problem solving reflecting different level of student understanding and metacognitive awareness identifying and categorizing these behaviors can help educators tailor instruction and support to individual learner need. Research into reasoning patterns also highlights the critical role of scaffolding and teacher guidance in promoting high order thinking skills by examining both cognitive and effective components such studies provide comprehensive insights into how students develop mathematical reasoning.

Rohati, Kusumah, and Kusnandi (2023) investigates how eighth grade students demonstrate mathematical reasoning when solving non routine problems through a grounded theory approach the researchers analyzed students written response and interviews across three Indonesian junior high schools categorizing reasoning behaviors into four types imitative algorithmic semi- creative and creative Imitative students rely on memorization and provide quick answers without understanding the reasoning behind them. Algorithmic students use formulas correctly but struggle with deeper understanding and justification semi creative students a newly identified category attempt multiple strategies and can reason with guidance while creative students indecently construct and justify their own rules test conjectures and show strong metacognitive skills and confidence.

The study presents a detailed rubric evaluating each category based on cognitive abilities meta reasoning (including monitoring and control both verbal and written) and self-confidence. The findings highlight how student behavior in mathematical reasoning progresses from rule following too independent and creative thinking metacognitive reasoning progresses from rule following to independent and creative thinking metacognitive control and teacher support play a vital role in this development semi creative students in particular benefit from scaffolding to build independence creative students demonstrate full integration of cognitive meta cognitive and affective components confidently justifying answers through patterns recognition and reasoning.

The study encourages teachers to use open ended tasks and interviews to assess students thinking and support transitions toward creative reasoning. While limited in scope this research offers a meaningful framework for improving instruction and understanding mathematical reasoning in the classroom calling for Broder studies across different educational levels and settings to further validate and apply its findings. Recognition and reasoning. The study encourages teachers to use open- ended tasks and interviews to assess student thinking and support transitions toward creative reasoning. While limited in scope, this research offers a meaningful framework for improving instruction and understanding mathematical reasoning in the classroom, calling for broader studies across different educational levels and settings to further validate and apply its findings.

2.2.31 Optimizing Mathematical Representation Skills through Quantum Teaching and Self-Esteem Enhancement

Mathematical representation skills are essential for students to communicate and understand mathematical concepts effectively developing these skills requires not only cognitive instruction but also attention to affective factor such as self-esteem which influences students' engagement and confidence integrating pedagogical learning models that foster both skill development and emotional growth can lead to more meaningful learning experiences. Quantum teaching with its structured student- centered approach provides an ideal framework for such integration by connecting real world context with active learning phase with active learning phase, its support students in representing mathematical ideas visually verbally and symbolically research exploring the synergy between instructional methods and psychological support highlights the importance of holistic approaches in mathematics education.

This perspective encourages educators to adopt strategies that nature both competence and self-confidence for enhanced mathematical understanding optimizing mathematical representation skills unveiling the synergy between quantum teaching and self-esteem by Supriadi et al. (2024) investigates how integrating the quantum teaching model with strategies for enhancing self-esteem can improve students' mathematical representation abilities namely visual verbal and symbolic representation. Conducted as a quasi-experimental study with 68 eighth grade students, the research divided participants into an experimental group taught through quantum teaching method and control group using discovery learning. Using validated tools and s self-esteem questionnaire and a mathematical representation test the study employed ANCOVA for analysis the results revealed that students taught using the quantum teaching model demonstrated significantly greater improvement in mathematical representation skills than those in the control group. Additionally, self-esteem was found to have and significant positive affect indicating that students with higher confidence achieved better mathematical understanding and expression and the value of integrating psychological support such as boosting self-esteem into mathematics instruction.

The study found that students with elevated self-esteem were more engaged and capable in mathematical task, while the structured and student-centered features of quantum teaching model provided and conducive environment for such growth. this model involves real world connections active learning and a staged process that encourages students to observe represent, and reflect. The authors conclude that combining quantum teaching with self-esteem enhancement offers and powerful holistic approach to improving both the academic and emotional development of students in mathematics these finding advocate for and shift from traditional teaching to move innovative learner centered strategies that foster both competence and confidence in mathematical reasoning and representation.

2.2.32 Quantum Teaching Method in Language and Writing Instruction

Improving student academic skills requires instructional methods that actively engage learners and address diverse learning styles Wahyuni (2022) conducted an experimental study to compare the effectiveness of the quantum teaching method and the direct instruction method in improving students' ability to write descriptive texts at the seventh-grade level at SMPP negeri 1 juwiring Indonesia. The study used and true experimental design involving and pretest and post control group with 64 students divided into experimental and control groups (32 each). The experimental group received instruction via quantum teaching, while the control group was taught through direct instruction.

The finding revealed and statistically significant difference showed and mean post test scores between the two groups. The experimental group showed and mean post test score of 82.75 compared to 71.44 for the control group. And t test showed the results were significant (Sig. (2-tailed) = 0.001 < 0.05), supporting the hypothesis that QTM is more effective in enhancing students writing skills moreover the calculated effect size (Cohen's d = 1.047) indicated a large effect of the intervention. The study highlights the border applicability of quantum teaching in fostering essential academic skills like writing. This research focuses on language instruction, its methodology and results align with the core principles of quantum teaching engaging learning environments, students centered instruction and multisensory techniques which are also relevant to the development of mathematical reasoning skills.

2.3 Theoretical Review

This study is supported by multiple learning theories that form the conceptual basis of the Quantum Teaching Method (QTM). These theories explain how student acquire knowledge, how skill is formed and how learning environments can be structed for optimal engagement and comprehension. The main theoretical frameworks include;

- Constructivism,
- Multiple Intelligences Theory
- Social Learning Theory

Each theory contributes and unique perspective to the quantum teaching model and directly informs the instructional strategies used in this study. Below each theory is discussed in detail along with its relevance to mathematical reasoning skills development.

2.3.1 Constructivism Theory

Constructivism is a learning theory rooted in the works of jean Piaget and lev Vygotsky asserting that learner actively construct knowledge through interaction with their environment and through meaningful experience. (Piaget, 1972) and (Vygotsky, 1978) rather than receiving information passively students build understanding based on prior knowledge and contextual learning. Piaget cognitive development theory describes how learner progress through stages, particularly emphasizing the concrete operational stage (ages 7-11) which aligns with elementary level mathematics instruction. In this stage students begin to apply logic to concrete situations making it an ideal period for introducing mathematical concepts like fractions making it an ideal period for introducing mathematical concepts like fraction product multiple decimals measurement and problem solving. Key principles of Constructivism include:

- Learners are active participants in their own learning.
- Knowledge is constructed rather than transmitted.
- Learning is most effective when it is relevant and situated in real-life contexts.

Teachers serve as facilitators, guiding exploration rather than delivering content. In practice constructivist classrooms emphasize inquiry-based learning students led discussions hand on activities and problem-based learning instruction is designed to activate prior knowledge challenges existing conceptions and foster reflection. These strategies lead to deep understanding and promote critical thinking. Quantum teaching aligns seamlessly with constructivist principle. In the QTM framework one of the core phases is experience before label which means students are first exposed to a concept through concrete experience before formal terminology is introduced. For instance, before naming and mathematical concepts such as equivalent fractions students might manipulate fraction tiles explore patterns in shaded areas or engage in real world activities involving partitioning through this process students build intuitive understanding before formal definitions are provided This approach supports the development of mathematical reasoning skills such as comparing analyzing synthesizing and justifying. As students engage with content experientially, they are better equipped to articulate their thinking draw logical conclusions and apply concepts across contexts. Constructivism reinforces the importance of making learning meaningful and connected to students lived experience which is at the heart of quantum teaching.

Moreover, Vygotsky's concept of the Zone of Proximal Development (ZPD) is critical in this context. It emphasizes the role of scaffolding or temporary support provided by teacher or peers to help students perform tasks they could not complete independently. QTM incorporates scaffolding through structured tasks peer collaboration and guided discovery ensuring that learners are supported while they grow in complexity and independence in their reasoning.

2.3.2 Multiple Intelligences Theory

Howard Gardner's Theory of Multiple Intelligences (1983) challenges the conventional notion of intelligence as and singular measurable trait instead Gardner posits that intelligence is multi-faceted and comprises at least eight distinct domains; linguistic, logical-mathematical, spatial, bodily-kinesthetic, musical, interpersonal, intrapersonal, and naturalistic intelligence (Gardner, 1983,). Each individual possesses all these intelligences to varying degrees and learns most effectively when instruction aligns with their strongest intelligence. this theory has far reached implications for educational practice. Rather than adhering to and one size fits all approach instruction must be varied to accommodate diverse learning profiles for example;

- Linguistic learners benefit from reading, storytelling, and discussions.
- Logical-mathematical learners thrive in problem-solving and analytical tasks.
- Spatial learners understand through visual aids, diagrams, and mapping.
- Bodily-kinesthetic learners excel with hands-on activities and movement.
- Musical learners respond well to rhythm, songs, or tonal cues.
- Interpersonal learners learn best through group work and collaboration. Intrapersonal learners benefit from self-reflection and independent tasks.
- Naturalistic learners engage with content through environmental connections.

The quantum teaching method incorporates and wide variety of learning modalities that address this multiple intelligence in and mathematics classroom this may include using music to teach patterns incorporating physical movement in learning geometric shapes visual representations for explaining data or peer teaching for promoting interpersonal learning these practices make abstract mathematical concepts more accessible especially for students who may struggle with traditional text based instruction. By utilizing multiple intelligence QTM helps create inclusive and engaging environments where each student's unique abilities are recognized and valued. This directly supports the development of mathematical reasoning by allowing students to approach problems in ways that resonate with their cognitive strengths. For example, a students and students with strong visual spatial intelligence may draw diagrams to understand and problem while and bodily kinesthetic learner may benefit from using manipulatives these personalized approaches not only improve comprehension but also boost confidence and motivation which are crucial for reasoning in mathematics. Furthermore, integrating multiple intelligences supports differentiated instruction allowing the teacher to provide multiple entry points to learning. This ensures that students are not only engaged but are also provided with the best opportunities to internalize process and apply mathematical reasoning skills in diverse contexts.

2.3.3 Social Learning Theory

Social Learning Theory, pioneered by Albert Bandura (1977), Emphasizes the importance of observing modeling and imitating the behaviors attitudes and emotional reactions of others. According to bandura most human behavior is learned observationally through modeling. People can learn new information and behaviors by watching others and then applying this knowledge to their own situations central concepts in this theory include:

- Observational learning (modeling)
- Vicarious reinforcement (learning through others' rewards and punishments)
- Self-efficacy (confidence in one's ability to succeed)
- Reciprocal determinism (interaction between person, behavior, and environment)

In the classroom environment social learning theory promotes collaborative learning peer feedback teacher modeling and group problem solving students not only learn academic skills but also social behaviors and reasoning strategies through interaction quantum teaching incorporates social learning theory by emphasizing social interaction cooperative learning and community building in the classroom. In and QTM environment students often work in pairs or small groups, which facilitates modeling and peer observation. When students solve problems together, they explain their thinking aloud listen to alternative strategies and receive feedback all of which enhance their reasoning skills. Teachers also play and vital role by modeling the use of reasoning strategies, such as thinking aloud while solving and math problem or demonstrating how to organize a solution logically. This modeling helps students internalize these strategies and use them independently. Additionally, the QTM framework emphasizes celebrating success and fostering and positive classroom climate which enhance student's self-efficacy and key factor in their willingness to engage with complex reasoning tasks. Through the combination of observational learning guided practice and collaborative dialogue social learning theory supports the development of reasoning by encouraging learners to reflect critique and build upon each other's ideas these interactive processes are essential for mathematical reasoning, where justification argumentation and clarity of thought are fundamental.

In conclusion the quantum teaching method is firmly grounded in multiple educational theories that collectively support the support the development of mathematical reasoning skills. Constructivism underscores experiential and reflective learning. Multiple intelligences theory ensures that instruction is responsive to diverse cognitive strengths promoting engagements where students learn through observation collaboration and modelling. Together these theories provide a robust foundation for the present study justifying the use of QTM as and means to enhance reasoning in elementary mathematics.

2.4 Empirical Review

This section provides a comprehensive review of pervious empirical studies related to the quantum teaching method and its impact on students' academic performance especially in enhancing mathematical reasoning skills.

2.4.1 Enhancing Writing Skills through Online Cooperative Learning

Aghajani and Adloo (2018) explored the impact of online cooperative learning using the telegram application on students writing skills and attitudes.

Conducted in an Iranians context the study utilized and quasi experimental design with control and experimental groups. Participants in the experimental group engaged in writing tasks via telegram allowing for real time peer interaction collaborative idea exchange and feedback the results revealed and statistically significant improvement in the writing skills of the experimental group compared to the control group moreover the students' attitudes towards writing improved due to supportive and interactive learning environment.

Although the focus was on language skills the relevance to quantum teaching lies in the cooperative student-centered approach and the use of digital platforms to enhance learning quantum teaching promotes active engagement social interaction and personalized learning. This research suggests that incorporating social and technological tools in instruction can enhance students reasoning and expression skills which can be adapted for use in mathematical learning environment.

2.4.2 Enhancing Critical Thinking through Quantum Teaching

Ramadhani and Ayriza (2019) conducted and study to examine the effectiveness of the quantum teaching model in improving critical thinking and social science concepts mastery among elementary school students. The researchers employed and pretest and posttest control group design to assess learning gains results showed that the experimental group receiving QTM instructional significantly outperformed the control group on both critical thinking and conceptual understanding assessments.

The study emphasized active learning through inquiry-based task group discussions reflection and real-world application all integral features of QTM the authors concluded that QTM fosters and deeper cognitive engagement by encouraging learners to construct knowledge actively and collaboratively. This finding is particularly pertinent to the current study's focus on mathematical reasoning where such thinking processes are essential.

2.4.3 Increasing Student Motivation in Social Studies

Khairunnisa (2018) investigated the effect of the quantum teaching method on student motivation in social studies at the elementary level, the quasi-experimental study included pretest and posttest intervention surveys to measure motivational changes finding revealed that students exposed to QTM demonstrated heightened enthusiasm improved attention spans and greater engagement compared to the control group.

The authors attributed these outcomes to the QTM use of varied instructional techniques games music storytelling and cooperative work which activated multiple learning modalities and encouraged active participation in mathematics education increased motivation is crucial for sustaining interest and perseverance in problem solving and abstract reasoning. Therefore, the study implications strongly support QTM use in nurturing mathematical reasoning.

2.4.4 Fostering Collaborative Thinking in Science

Nahar et al. (2022) explored the implementation of Quantum Teaching to develop collaborative thinking skills among science students. The study employed a mixed-methods approach, combining quantitative data from achievement tests with qualitative data from classroom observations and interviews. The results showed improved group dynamics, increased student talk, higher levels of peer interaction, and better problem-solving capabilities.

This study is significant because mathematical reasoning often requires learners to articulate their ideas, evaluate alternatives, and arrive at conclusions through discussion. QTM's emphasis on collaborative inquiry and reflective practice mirrors these cognitive demands. As such, this research supports the adaptation of QTM for developing mathematical reasoning through peer learning and discourse.

2.4.5 Improving Writing Skills through Quantum Teaching

Wahyuni (2022) conducted a study at SMP Negeri 1 Juwiring to evaluate the effect of the Quantum Teaching method on students' writing abilities, specifically in crafting descriptive texts. The study employed a true experimental design with pre- test and post-test procedures applied to both experimental and control groups. The experimental group received instruction via the Quantum Teaching framework, while the control group followed the direct instruction method.

The results demonstrated a significant increase in the writing scores of the experimental group. The mean score rose from 46.94 in the pre-test to 82.75 in the post-test, indicating substantial improvement. The Quantum Teaching method’s incorporation of the TANDUR cycle (Tumbuhkan, Alami, Namai, Demonstrasikan, Ulangi, Rayakan) allowed students to engage actively and emotionally in the learning process, which in turn enhanced their cognitive performance. this study aligns with the principles of constructivism and multiple intelligences as it emphasizes hands-on experience, group discussions, and multimodal teaching strategies key aspects relevant to improving mathematical reasoning.

2.4.6 Enhancing Science Learning Outcomes through QTM

Sabillah and Sukmawati (2020) investigated the effectiveness of the Quantum Teaching model in enhancing science learning outcomes among fifth-grade students in SD Borong Jambu II Makassar. The study revealed that integrating Quantum Teaching with varied instructional media such as visual and audio aids improved student engagement and retention of science concepts Through classroom action research, the authors showed how each phase of the TANDUR cycle contributed to meaningful learning. Students developed critical thinking and reasoning skills by connecting prior knowledge with new content in a collaborative setting. Although this research focused on science subjects, the instructional methods and cognitive benefits are transferable to mathematics education, particularly in fostering reasoning and analytical skills.

2.5 Critical summary

The reviewed literature on the Quantum Teaching Method (QTM) presents a broad and in-depth exploration of its impact on educational outcomes, with a particular focus on mathematical reasoning and learning in elementary and secondary settings. Across multiple studies, the QTM has consistently demonstrated its effectiveness in improving student engagement, motivation, academic achievement, and higher-order thinking skills. This teaching approach is characterized by structured stages—most commonly the TANDUR framework (Tumbuhkan, Alami, Namai, Demonstrasikan, Ulangi, Rayakan)—which are designed to create meaningful and emotionally resonant learning experiences. These phases are not only cognitively stimulating but also strategically organized to foster student-centered environments, aligning closely with contemporary educational theories such as Constructivism, Multiple Intelligences Theory, and Social Learning Theory. One of the key strengths of the literature lies in its consistent reporting of improvements in students' mathematical learning outcomes. Studies such as those by Jayantika et al. (2019), Roviani (2023), and Arum and Amir (2019) showed clear increases in student scores and mastery levels after implementing QTM. These gains were observed across different cycles of classroom action research, indicating that iterative and reflective application of the method yields progressively better results. Additionally, findings revealed that QTM not only enhances cognitive performance but also plays a significant role in building affective attributes such as confidence, self-efficacy, and a positive attitude toward mathematics, particularly among low- and medium- performing students. The literature also underscores the adaptability and scalability of QTM across different subjects and educational levels. Although the primary focus was on mathematics, studies in science, social studies, and language instruction affirmed the model's universal pedagogical benefits. Research by Larasati and Baadilla (2023) and Putri et al. (2024), for instance, confirmed that QTM enhances engagement and conceptual understanding across disciplines, suggesting its potential to support integrated and interdisciplinary learning. These studies support the idea that the method's structure emphasizing experiential learning, real-life relevance, peer collaboration, and emotional connection serve as a robust pedagogical framework for diverse educational contexts.

However, despite these promising findings, the literature is not without its limitations. Many of the studies rely heavily on localized samples from Indonesia or similarly structured educational systems, which raises questions about the generalizability of the results to other cultural or institutional contexts. Furthermore, the majority of studies employ short-term experimental or action research designs, providing limited insights into the long-term retention of skills or the sustainability of QTM's effects over time. Another limitation lies in the inconsistency of assessment tools for measuring reasoning skills. While some studies, such as those by Rohati et al. (2023) and Napitupulu (2017), offer rigorous rubrics and frameworks for evaluating mathematical reasoning, others measure learning outcomes primarily through test scores, without fully capturing the nuances of students' reasoning processes.

The integration of QTM with other instructional strategies such as Hypnoteaching, problem- based learning, the Make-a-Match method, and the use of animation media further enriches the teaching process and demonstrates the model's flexibility. These combinations have been shown to be particularly effective in enhancing student engagement and deepening conceptual understanding. For example, the use of Hypnoteaching techniques by Novianti & Mulyaning (2020) helped reduce student anxiety and increased emotional involvement in mathematical tasks. Similarly, the incorporation of real-world applications and visual aids, as demonstrated in studies like Mahendra (2022), made abstract concepts more tangible and accessible, which is crucial for developing mathematical reasoning.

The theoretical grounding of QTM in Constructivism highlights its emphasis on experiential and reflective learning. Students are encouraged to build understanding through concrete experiences before being introduced to formal terminology, which supports deeper cognitive processing. The alignment with Multiple Intelligences Theory ensures that the method addresses diverse learning styles, thereby making instruction more inclusive and effective. Social Learning Theory complements this by emphasizing observational learning, peer collaboration, and the modeling of reasoning strategies—all of which are essential components of effective mathematical instruction. These theoretical underpinnings validate QTM's design and support its application as a research-based, student-centered approach to teaching.

In conclusion, the collective body of literature presents Quantum Teaching as an innovative and effective pedagogical model that significantly enhances not only mathematical achievement but also the reasoning, motivation, and confidence of students. The model's structured and holistic approach is capable of transforming passive learning environments into dynamic and engaging classrooms. Nonetheless, future research should aim to broaden the scope of investigation through longitudinal studies, standardized reasoning assessments, and cross-cultural application to fully establish the long-term impact and universal applicability of the Quantum Teaching Method.

CHAPTER 3
RESEARCH METHODOLOGY

In Chapter 3, the research methodology was comprehensively detailed, outlining the approach and techniques employed to investigate the study's objectives. The chapter includes the research approach, design, population, sample selection, tools used, data collection steps, how the tools were tested for accuracy and consistency, methods of data analysis, and the ethical steps taken to protect participants.

3.1 Research Design

This study utilizes and quantitative approach with and quasi- experimental design to investigate the effect of the quantum teaching method on elementary students mathematical reasoning skills.

3.2 Population

The population of the study consisted of Garde IV students who were enrolled in N=76 public schools in the Sihala sector of Islamabad Pakistan. This demographic was selected based on their important stage of cognitive development, which aligned with Piaget's concrete operational stage. where learners had begun to develop logical thinking abilities and were capable of understanding mathematical reasoning.

3.3 Sample and Sampling Technique

The sample of the study was Garde 4 students at Islamabad Model College for Boys (IMCB) Pakistan Town. A random sample technique was used for the study the sample consisted of n = 62 grade 4 students who were divided in two pre-existing groups of 31 students each. One group was experimental group which received instruction through quantum teaching method while other group was control group as was taught using direct instruction method.

3.4 Instruments

3.4.1 Introduction to the Instrument

The effectiveness of any educational intervention must be assessed using and valid and reliable instrument aligned with the cognitive goals of the study. To measure the effect of quantum teaching method on the mathematical reasoning skills of Garde IV students and specialized assessment tool titled the Mathematical Reasoning Test (MRT) was developed by the researcher. The MRT served as the primary instrument for data collection in the experimental study.

The MRT was researcher developed instrument carefully constructed to assess students reasoning skills in mathematics. It was conceptually adapted from the Trends in International Mathematics and Science Study (TIMSS) 2019 mathematics framework, published by the TIMSS and PIRLS international study center at Boston college (Mullis et al., 2019) It is important to emphasize that the MRT did not include any direct items from the TIMSS question bank. Instead, all items were originally authored by the researcher.

The TIMSS framework was selected for several pedagogical and methodological reasons. Firstly, it provides a comprehensive and researcher-based model for assessing mathematical competencies with and strong focus on reasoning. Which was the core skill targeted in the study. TIMSS identifies three major cognitive domains knowing applying and reasoning. Of these the reasoning domain which include abilities such as analyzing synthesizing generalizing and justifying is particularly relevant to the goal of quantum teaching method, which emphasize the development of analytical critical thinking skills and mathematical reasoning skill in students. In the TIMSS 2019 fourth grade assessment design reasoning constitutes 20% of the overall cognitive domain weightage highlighting its importance in international mathematics education

Secondly the TIMSS framework is publicly available and open access designed for use by educator’s curriculum developers and researchers. Therefore, its adaptation for academic research purposes does not require formal permission or licensing making it suitable for use as a references model in the study. The MRT although guided by TINSS principles remains a researcher- developed tool specifically tailored to the cognitive and curricular context of grade IV students in Pakistan.

The development of the MRT ensured a high degree of alignment with both international standard and national curriculum expectations. According to the TIMSS 2019 mathematics framework key mathematical content domains for grade IV students include Numbers measurement geometry and data with particular emphasis on topics such as whole numbers factors and multiples and fractions. These areas are identified in the TIMSS framework as fundamental components for developing students understanding of numeric relationship and reasoning ability the present study focused Recognizing the importance of these domains, the present study focused on the three content areas of factors, multiples, and fractions, which are also integral to the Grade IV Mathematics Curriculum prescribed by the Federal Directorate of Education (FDE), Pakistan.

Accordingly, these topics were intentionally selected and incorporated into the MRT to ensure consistency with both the TIMSS framework and national educational standards. This deliberate selection of overlapping content ensured that the test not only assessed reasoning in a globally benchmarked context but also remained relevant, appropriate, and meaningful for the local classroom setting.

3.4.2 Structure of the Mathematical Reasoning Test (MRT)

The MRT consisted of 20 multiple choice items with each question targeting on four key reasoning domains; comparing contrasting generalizing and justifying. These domains reflect the border TIMSS cognitive category of reasoning which includes higher order cognitive processes such as drawing inference providing justification identifying patterns and making generalizations each reasoning domain was represented by five questions ensuring and balanced distribution and comprehensive assessment of students reasoning skill.

3.4.3 Mathematical Reasoning Skills

- Comparing: this domain included items that required students to identifying similarities between mathematical elements.
- Contrasting: this domain included distinguishing differences between mathematical concepts
- Generalizing: these items assessed students’ ability to recognize mathematical patterns and rules.
- Justifying; in this domain asked students to provide logical explanation or reasons for their choices.

3.4.4 Table of Specification (TOS) for the Mathematical Reasoning Test (MRT)

Table 3.4.4

Table of Specification

Units	Comparing	Contrasting	Generalizing	Justifying	Total Items
The Factor Forest and Multiple Mountains Adventure	2	2	2	2	8
Fraction Frenzy in Fraction Ville	3	3	3	3	12
Total	5	5	5	5	20

3.4.5 Question Format and Language

All 20 items were developed in multiple choice format each with four answer options and one correct response. This format was chosen to facilitate objective scorning and to eliminate potential biases in subjective evaluation. The language used in all items was age appropriate concise and free complex terminology.

3.4.6 Time Allocation and Administration

The total time allotted for completing the test was 45 min which was based on pilot testing feedback and classroom experiences regarding the attention span of grade IV students. The duration was sufficient for students to engage in reasoning tasks the test was administered in and controlled classroom environment under the supervision of the researcher to ensure standardized conditions

3.5 Procedure (Validity, Pilot Testing and Reliability)

The implementation of this study followed and systematic procedure that ensured the accuracy consistency and credibility of the research instruments and outcomes the overall procedure consisted of three main phases; validation of the instrument pilot testing and establishment of reliability.

3.5.1 Validity

To ensure content validity the Mathematical Reasoning Test (MRT) was subjected to and detail expert validation process. And panel of six professionals participated in the validation two of the reviewers were faculty members from the department of teacher education at the international Islamic university Islamabad. Possessing doctoral qualification and expertise in educational research. One expert was and mathematics specialist from the Jakson education system. The remaining three experts were educational professionals from IMCB Pakistan Town including the school principal the head teacher and a grade IV mathematics teacher. Their expertise ensured the tests relevance and appropriateness for grade IV students. Particularly regarding age suitability and alignment with federal directorate of educations curriculum the panel was provided with and complete version of the test. Operational definitions of each reasoning domain ((comparing, contrasting, generalizing, justifying). And validation checklist containing criteria such as content relevance clarity of language age appropriateness curriculum alignment and cognitive demand.

The experts evaluated each item against these benchmarks. Based on their feedback necessary revisions were made to the wording difficulty level and sequencing of questions to improve clarity and measurement accuracy. The panel unanimously approved the final version of the test signed validation certificates have been included in the appendices.

3.5.2 Pilot Testing

A pilot study was conducted prior to the main data collection phase to evaluate the feasibility clarity and age appropriateness of the mathematical reasoning test (MRT). The pilot sample consisted of 20 students enroll in grade IV in 2024 at Islamabad Model College for Boys (IMCB) Pakistan town a school that was not part of the main study sample. The test administration environment reflected the actual classroom setting to simulate real conditions. During pilot testing the researcher observed students’ responses recorded time taken per item and identified any ambiguous or confusing questions feedback from students and observations were used to refine the instrument further. The pilot phase helped verify that the test instructions were clear questions were age appropriate and the test could be completed within the allotted time.

3.5.3 Reliability Testing

Table 3.5.3

Reliability

Reliability Measure	Value	Items
Spearman-Brown Coefficient	0.75	20

Table3.5.3 presents that the Spearman-Brown coefficient for the Mathematical Reasoning Test, which was calculated to be **0.75**. This value shows a good level of internal consistency, indicating that the test items are reliably measuring the same construct mathematical reasoning skills.

3.6 Threats and Steps to Control Internal and external Validity Threats

3.6.1 Internal Validity Threats

Threat	Description	Control Measures
History	External events occurring during the study period (e.g., holidays, school functions) may influence students' academic achievement.	Both groups were taught the same content under similar conditions, minimizing the influence of external events on academic performance.
Maturation	Natural changes in students' cognitive development over time could affect results.	Students were of similar age and developmental stage. The relatively short intervention period (two months) helped reduce maturation effects.
Selection	Pre-existing differences between groups due to non-random assignment could impact outcomes.	Random assignment was employed to ensure both groups were equivalent at baseline, thus minimizing selection bias.

3.6.2 External Validity Threats

Threat	Description	Control Measures
Selection and Treatment Interaction	The population, limiting and setting may reduce generalizability.	Clear description of the population and setting was provided to support future replication and comparison.
Setting and Treatment Interaction	The unique environment of the Federal Government Primary School, Islamabad, may influence results and limit generalization.	Both groups were taught in similar classroom settings by the same instructor, reducing environmental biases and improving internal consistency.
History and Treatment Interaction	Unique events during the study period may limit how results apply to other times or contexts.	The short, two-month study period minimized the likelihood of major external disruptions. Any notable events were documented for transparency.

Campbell (1979, as cited in Creswell, 2012) had mentioned the following external threats which were controlled by researcher.

3.7 Intervention Plan

This experimental study involved a carefully structured eight-week instructional intervention conducted from April 7 to June 4 2025 to evaluate the effectiveness of the quantum teaching method in enhancing mathematical reasoning skills among grade IV students. The intervention focused on nine key topics from the official mathematics curriculum taken from unit the fact forest and multiple mountains adventure and unit fraction frenzy in fraction ville as prescribed by the federal directorate of education (FDE) Islamabad.

Both the experimental group and the control group consisted of 31 students each. Each group received instruction on same topics using 26 structured lesson plans for each group but through distinctly different teaching methodologies and the researcher served as the teacher for both groups.

3.7.1 Phase 1: Pre-Test Administration

The intervention commenced with and pretest administered to both groups on April 7 2025 the instruments used was the mathematical reasoning test (MRT) validated through expert review and designed to assess students baseline reasoning skills in four domains comparing contrasting generalizing and justifying.

3.7.2 Phase 2: Instructional Intervention

The instructional intervention covered approximately eight weeks excluding public holidays between May 7-12 the implementation included:

- Total Topics: 9
- Total Lesson Plans: 26
- Class Duration: 50 minutes per session
- Weekly Frequency: 5 sessions per week

3.7.3 Experimental Group: Quantum Teaching Method

The experimental group was instructed using the quantum teaching method and student-centered approach designed to create engaging meaningful and emotionally safe learning environment. Each lesson was structured around the EEL DR C framework:

- Enroll: Introduced the topic using real-world context or storytelling to engage students emotionally and cognitively.
- Experience: Allowed students to explore mathematical concepts through activities, games, or manipulatives.
- Label: Introduced formal mathematical vocabulary and notation linked to students'
- prior experiences.
- Demonstrate: Teacher modeled problem-solving strategies while students practiced collaboratively.
- Review: Students reflected on their learning through guided discussion, summaries, or journals.
- Celebrate: Each lesson ended with recognition of student effort and accomplishment, enhancing motivation and retention.

This method emphasized collaborative learning, multiple intelligences, and real-life application, fostering deeper levels of understanding and reasoning.

3.7.4 Control Group: Traditional Direct Instruction Method

The control group received the same content using the traditional direct instruction method This teacher-centered approach included:

- Lecturing and board work
- Step-by-step demonstrations
- Textbook-based problem solving
- Independent seatwork and repetition exercises

3.7.5 Weekly Implementation Schedule

Table 3.7.5 Weekly Implementation Schedule

Week	Date Range	Topic(s)
Pre-Test		Pre-Test Administration – Topic 1: Divisibility Rules
1	April 7 – April 11	Topic 1: Divisibility Rules – Rule of 2
2	April 14 – April 18	Topic 1: Divisibility Rules – Rules of 3, 5, and 10 Topic 2: Factors and Multiples – Identifying Factors Topic 2: Finding Multiples & Common Factors/Multiples Practice Session on Factors and Multiples
3	April 21 – April 25	Topic 3: Prime Numbers Topic 3: Composite Numbers Practice & Review (Prime vs Composite) Topic 4: Converting Improper Fractions to Mixed Numbers
4	April 28 – May 2	Topic 4: Converting Mixed Numbers to Improper Fractions Practice Session on Conversions
5	May 5 – May 9	Topic 5: Comparing Like Fractions Topic 5: Comparing Unlike Fractions *(Holidays: May 7 – May 12, no new lessons)*
6	May 13 – May 16	Topic 6: Adding Like Fractions Topic 6: Adding Unlike Fractions Topic 7: Subtracting Like and Unlike Fractions

Week	Date Range	Topic(s)
7	May 19 – May 23	Topic 8: Multiplying a Fraction by a Whole Number Topic 8: Multiplying Two Fractions Topic 9: Dividing a Fraction by a Whole Number Topic 9: Dividing Fractions (Conceptual and Procedural Practice)
8	May 26 – June 4	Real-World Problems Involving Addition of Fractions Real-World Problems Involving Multiplication and Division of Fractions Revision – Unit 4 Topics Revision – Unit 5 Topics June 4: Post-Test Administration

3.7.6 Phase 3: Post-Test Administration

On 4th June 2025 posttest was administered to both the experimental and control groups using the same MRT that had been used during the pretest phase.

3.7.7 Curriculum Topics Covered

- Divisibility Rules
- Factors and Multiples
- Prime and Composite Numbers
- Converting Fractions
- Comparing & Ordering Fractions
- Adding & Subtracting Fractions
- Multiplying Fractions
- Dividing Fractions
- Real-world Fraction Problems

3.8 Data Collection

The data collection process took place over an eight-week period beginning on April 7 2025 and concluding on June 4 2025. During this time the experimental group received instruction through the quantum teaching method and control group received instruction through direct instruction method. The aim of data collection was to systematically capture students mathematical reasoning skill sunder both conditions.

3.8.1 Instruments Used

The main instrument used were the Mathematical Reasoning Test (MRT) which assessed four domains of reasoning comparing contrasting generalizing and justifying. The (MRT) was administered during the following stages;

- Pre-Test: Conducted on April 7, 2025, before the start of the intervention to determine baseline reasoning levels.
- Post-Test: Conducted on 4 June, 2025

3.9 Data Analysis

Quantitative data obtained from MRT was processed using (Statistical Package for the Social Sciences). The following statistical techniques were applied:

3.9.1 Descriptive Statistics

Calculation of mean scores, standard deviations, to summarize the data.

3.9.2 Inferential Statistics

In inferential statistics Independent Samples t-test was used to compare the post-test scores of the experimental and control groups. And paired t test was use to compare pretest and posttest with in group.

3.10 Ethical Considerations

Ethical considerations were taken seriously throughout the research process; written consent was obtained from students' parents or guardians before participating. All data were kept confidential, and participants were anonymized in the reporting of results. Participants were informed of their right to withdraw from the study at a time without penalty. The study ensured that no psychological, emotional or physical harm came to the participants. The intervention and data collection procedures were designed to be non-intrusive and respectful of students' well-being.

CHAPTER 4

DATA ANALYSIS AND INTERPRETATIONS

This chapter presents an in-depth analysis and interpretation of the data collected from the control and experimental group to determine the effect of the quantum teaching method on the mathematical reasoning skills of grade 4 students. The objective of this analysis is to assess the difference in academic performance before and after the implementation of the quantum teaching method and compare the outcomes between the experimental and control groups. The chapter begins with descriptive statistics detailed analysis of pretest and post test results inferential statistics and interpretation of findings. Statistical tools such as mean standard deviation t-test and paired t- test were used for data analysis test SPSS software was employed for statistical calculations.

4.1 Descriptive Statistics of Pre-Test Scores for Experimental and Control Groups

Descriptive statistics were calculated for the pretest score of both the experimental and control groups. These statistics help determine the initial level of mathematical reasoning skills before any instructional intervention.

Table 4.1

Descriptive Statistics of Pre-Test Scores for Experimental and Control Groups

Group	N	Minimum	Maximum	Mean	Standard Deviation
Experimental	31	2	9	4.16	1.72
Control	31	2	9	4.16	1.72

Table 4.1 shows that the descriptive statistics for the pretest scores of the experimental and control groups. The experimental group (n = 31) obtained a mean pretest score of 4.16 with and standard deviation of 1.720, while the control group (n= 31) also achieved a mean score of 4.16 with an identical standard deviation off 1 720. the scores in both groups ranged from and minimum of 2 to maximum of 9 indicating and similar distribution of student performance. These findings suggest that both groups exhibited comparable levels of mathematical reasoning skills prior to instructional intervention. The identical means and standard deviations confirm and well-balanced starting point across the

groups which is essential for maintaining internal validity in and quasi experimental design.

4.2 Paired Samples Statistics for Pretest and Post-test Scores

Pretest and posttest of experimental group to find the effect of quantum teaching method on student mathematical reasoning skill at elementary level.

Table 4.2

Paired Samples Statistics for Pretest and posttest scores (experimental group)

Test	Mean	N	Standard Deviation
Pre-Test	4.16	31	1.72
Post-Test	15.39	31	1.86

Table 4.2 showed that the paired samples statistics for the pretest and post test scores of the experimental group. The pretest score with standard deviation of 1.720 while the post means significantly increased to 15.39 with and standard deviations of 1.856 both tests involved 31 students this substantial improvement in mean scores suggests that the quantum teaching method has and positive effect on mathematical reasoning skill of students in the experimental group.

4.3 Paired Samples t-Test Results for Pretest and Posttest Scores

Table 4.3

Paired Samples t-Test Results for Pretest and Posttest Scores (Experimental Group

Test Pair	Mean	Std. Deviation	95% Confidence Interval of the Difference Lower
Pretest – Post-test	11.23	2.91	10.16

Table 4.3 showed that the results of paired sample t-test conducted to compare pretest and post test scores of the experimental group. The mean difference between the pretest and post test score was 11.26with and standard deviation of 2.906 the 95% confidence interval for the mean difference ranged from 12.292 to 10.160 indicating that the improvement in the score is statistically significant. these findings confirm that the

Quantum Teaching Method had a statistically significant and positive effect on students' mathematical reasoning skills in the experimental group.

4.4 Paired Samples Statistics for Pre-Test and Post-Test Scores

Table 4.4

Paired Samples Statistics for Pre-Test and Post-Test Scores (Control Group)

Test	**Mean**	**N**	**Standard Deviation**
Pre-Test	4.16	31	1.72
Post-Test	10.68	31	0.98

Table 4.4 presents the descriptive results of the pre-test and post-test scores for the control group, which was taught using the traditional (Direct Instruction) method. The results show that the mean pre-test score was 4.16 with a standard deviation of 1.72**,** while the mean post-test score increased to 10.68 with a standard deviation of **0.98**. This indicates that the control group showed an improvement of 6.52 points on average after receiving traditional instruction. The lower standard deviation in the post-test (0.98) compared to the pre-test (1.72) suggests that the students' performance became more consistent after the intervention, with less variability among scores.

4.5 Paired Samples t-Test Results for Pretest and Posttest Scores

Table 4.5

The paired samples t-test was conducted to compare the pretest and posttest scores of the control group, which was taught using the traditional (Direct Instruction) method.

Test Pair	**Mean Difference**	**Std. Deviation**	**95% Confidence Interval of the Difference**
Pre-Test – Post-Test	6.52	2.18	5.84 – 7.20

Table 4.6 presents the results of the paired samples *t*-test conducted to compare the pre-test and post-test scores of the control group. The findings show a mean difference of

6.52 with a standard deviation of 2.18, and the 95% confidence interval for the meandifference ranged from 5.84 to 7.20.

This indicates that the students in the control group demonstrated a statistically significant improvement in their mathematical reasoning scores from pre-test to post-test, suggesting that learning occurred through the traditional (Direct Instruction) teaching method. However, the magnitude of improvement was smaller compared to the experimental group, which achieved a higher mean difference (11.2).

4.6 Descriptive Statistics for Pretest and Posttest Scores by Group

This table presents the mean scores, standard deviations, and standard errors for both experimental and control groups in pretest and posttest phases, providing an overview of group performance before and after the intervention.

Table 4.4

Descriptive Statistics for Pretest and Posttest Scores by Group

Test Score	Group	Mean	Std. Deviation
Pre-Test Score	Experiment	4.16	1.72
	Control	4.16	1.72
Post-Test Score	Experiment	15.39	1.86
	Control	10.68	0.98

Table 4.4 presents that descriptive statistics for experimental and control groups during the pretest and posttest phases. The pretest result show identical mean score of 4.16 for both groups along with equal standard deviations 1.720 indicating that the groups had same baseline before the intervention. After the implementation of instructional methods, the experimental group which received quantum teaching method and achieved and much higher posttest mean score 15.39 whereas the control group reached and mean of 10.68. the marked improvement in the experimental group suggests that the quantum teaching method had and significantly positive impact on enhancing students mathematical reasoning skills compared to the traditional teaching approach used with the control group.

4.7 Independent Samples t-Test Results for Pretest and Posttest Scores by Group

The independent sample t-test was conducted to compare the mean score of the groups.

Table 4.7

Independent Samples t-Test Results for Posttest Scores by Group

					Levene's Test for Equality of Variances	**t-test for Equality of Means**		
	F	Sig	T	df	Sig.(2-tailed)	Mean differences	95% confidence interval of the difference Lower	Upper
Equal variances assumed Post test scores	23.358	.000	12.495	60	.000	4.710	3.956	5.464

Table 4.5 showed that the independent samples t-test was performed to compared the post test scores of the students in the experimental group and control group levenes test for equality of variance indicated that and significant results (F= 23.358 , p =.000) suggesting that the assumption of homogeneity of variance was violated therefore the results were interpreted using the row of equal variance not assumed the analysis revealed and statistically significant difference between two groups t(45.503)-12.495,p< .001. the mean difference in and post test score was 4.710 with and 95%confidence interval ranging from 3.951 to 5.469. this indicates that students in the experimental group performed significantly better than those in the control group

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4.8 Descriptive Statistics of Mathematical Reasoning Skills

Table 4.8

Descriptive Statistics of Mathematical Reasoning Skills (Experimental Group)

Skill Type	N	Minimum	Maximum	Mean	Std. Deviation
Comparing (Pretest)	31	1	4	3.23	1.146
Justifying (Pretest)	31	0	1	0.03	0.180
Generalizing (Pretest)	31	0	0	0.00	0.000
Contrasting (Pretest)	31	0	4	0.90	1.221
Contrasting (Posttest)	31	4	4	4.00	0.000
Comparing (Posttest)	31	4	4	4.00	0.000
Justifying (Posttest)	31	4	4	4.00	0.000
Generalizing (Posttest)	31	1	4	2.84	1.241
Valid N (listwise)	31				

Table 4.6 showed that the descriptive statistics for four mathematical reasoning skills Comparing, Justifying, Generalizing, and Contrasting measured during the pretest and post phases for the experimental group. in the pretest the highest mean was observed in comparing (M=3.23, SD=1.146) showed that student had a relatively better grasp of this skill before the intervention. in justifying the mean score is M=0.03 and SD= 0.180 in generalizing the mean score M= 0.00 and SD= 0.000 and contrasting the mean score is M= 0.90 and SD= 1.221 which reflect limited initial understanding After the intervention posttest substantial improvements were evident across all skill types. Comparing justifying and contrasting all reached the maximum possible score with means of 4.00 and standard deviations of 0.000 indicating perfect performance and no variation among students everyone achieved full marks in these domains. Generalizing also showed notable progress with and posttest mean of 2.84 (SD= 1.241) although there was still some variation among students.

4.9 Paired Samples t-Test Results for Reasoning Skill Domains

Table 4.9

Paired Samples t-Test Results for Reasoning Skill Domains (Experimental Group)

Skill Domain	Mean Difference	Std. Deviation	t	df	Sig. (2-tailed)
Comparing (Pre–Post)	-0.774	1.146	-3.760	30	.001
Contrasting (Pre–Post)	-3.097	1.221	-14.124	30	.000
Justifying (Pre–Post)	-3.968	0.180	123.000	30	.000
Generalizing (Pre–Post)	-2.839	1.241	-12.737	30	.000

Table 4.7 showed that the results of paired samples t-tests conducted to evaluate the effectiveness of the quantum teaching method on four mathematical skill domains comparing contrasting justifying and generalizing within experimental group. for the comparing skill a mean difference of 0.774 (SD = 1.146) was observed with and t- value of 3.760 and a significance level of p = .001. this result indicates and statistically significant improvement in students' ability to compare mathematical concepts following the intervention, for the contrasting skill and mean differences of 3.097 (SD = 1.221) with and highly significant t – value of 14.124 (P < .001) reflecting improvement in students. for the justifying skill the mean difference of 3.968 (SD = 0.180) and high t – value of 123.00 also significant at p < .001. this suggests nearly all students improved to the highest possible level in this domain. for the Generalizing domain the mean difference was 2.839 (SD = 1.241), with and t – value of 12.737 and a significance level of p < .001. This showed that students developed their ability to generalizing skill.

4.9.1 Summary

This chapter presents an in-depth analysis and interpretation of the data collected from the control and experimental group to determine the effect of the quantum teaching method on the mathematical reasoning skills of grade 4 students The chapter begins with descriptive statistics detailed analysis of pretest and post test results inferential statistics and interpretation of findings. Statistical tools such as mean standard deviation t-test and paired t-test were used for data analysis test SPSS software was employed for statistical calculations.

The pre-test scores of both the experimental group and control group were compared initially. The results showed that experimental and control groups started at similar levels, with comparable means and standard deviation, supporting the internal validity of the study. This balance ensured that any observed changes in post- test outcomes could be attributed to the instructional method rather than to differences in baseline abilities.

The implementation of the Quantum Teaching Method in the experimental group, a significant improvement in students' high mathematical reasoning skill was observed. The post-test scores of the experimental group increased significantly compared to their pre-test of the experimental group Statistical analysis showed that this enhancement was highly significant, indicating the effectiveness of the quantum method in enhancing mathematical reasoning skills.

A further comparison between the post-test scores of the experimental and control groups revealed a significant difference in favor of the experimental group. This finding reinforced the conclusion that students who were taught using the Quantum Teaching Method outperformed those who received traditional instruction. In addition to overall test performance, the study also assessed students’ abilities across four key reasoning domains: comparing, contrasting, justifying, and generalizing. The pre-test results in these areas showed generally low performance, particularly in justifying and generalizing. However, the post-test scores showed dramatic improvements across all four skill areas, with students demonstrating mastery in comparing, contrasting, and justifying, and substantial gains in generalizing.

The statistical significance of these gains was confirmed through paired samples t-tests, further validating the effectiveness of the intervention. The results provide strong evidence that the Quantum Teaching Method not only improved students’ academic performance but also contributed to the development of higher- order thinking and reasoning skills. Overall, the findings of this chapter affirm that the Quantum Teaching Method had a positive and meaningful impact on the mathematical reasoning abilities of students at the elementary level.

CHAPTER 5
SUMMARY, FINDINGS, DISCUSSION, CONCLUSIONS AND RECOMMENDATIONS

This chapter presents a comprehensive overview and interpretation of the research findings. It begins with a summary of the entire research process, including the objectives, methodology, and results covered in the preceding chapters. It then outlines the major findings in relation to the research questions and provides a detailed discussion by comparing the results with existing literature. The chapter also includes numbered conclusions drawn directly from the findings and offers practical recommendations for teachers, school leaders, and curriculum developers.

5.1 Summary

This research study was conducted to explore the impact of the Quantum Teaching Method on the development of mathematical reasoning skills among elementary school students. The study emerged from the recognition that traditional teaching methods in mathematics often rely heavily on memorization and procedural drills, which do not adequately foster students' ability to reason logically, justify their answers, or apply concepts in diverse contexts. Many students, especially at the elementary level, can perform mathematical operations but struggle to explain the reasoning behind them or use alternative strategies. To address this issue, the researcher implemented the Quantum Teaching Method, a comprehensive teaching strategy based on brain-based learning, emotional involvement, and interactive classroom experiences. This method emphasizes a six-stage instructional cycle Enroll, Experience, Label, Demonstrate, Review, and Celebrate designed to create a vibrant and engaging learning environment that supports students' cognitive, emotional, and social development. The study was conducted using a true experimental research design under a post- positivist paradigm. A school was randomly selected from the list of public schools in the Sihala sector of Islamabad, and the participants were drawn from Grade IV students enrolled at Islamabad Model College for Boys (IMCB), Pakistan Town. A total of 62 students were selected and thenrandomly assigned to two equal groups: an experimental group and a control group, each comprising 31 students.

The experimental group was taught using the Quantum Teaching Method, based on the EEL DR C model (Enroll, Experience, Label, Demonstrate, Review, Celebrate), while the control group received instruction through traditional direct teaching methods. The instructional content included selected topics from the official mathematics curriculum, particularly factors and multiples and fractions, covering divisibility rules, conversions, ordering, and arithmetic operations involving fractions and real-world problems.

To assess students' reasoning ability, the researcher used a Mathematical Reasoning Test (MRT) adapted from the internationally recognized TIMSS 2019 Mathematics Framework. The MRT consisted of 20 multiple-choice questions, equally divided across four reasoning domains: comparing, contrasting, generalizing, and justifying. All test items were originally developed by the researcher based on TIMSS principles and aligned with the local Grade IV curriculum. The test was reviewed by educational experts for content validity, pilot-tested with a similar student group, and statistically tested for reliability, resulting in a Guttman Split-Half Coefficient of 0.76, confirming strong internal consistency.

Data were collected through pre-tests, post-tests, and retention tests, and analyzed using SPSS software. Descriptive statistics (mean, standard deviation,) were used to describe student performance, while paired samples t- tests and independent samples t-tests were applied to determine whether the differences between and within groups were statistically significant.

5.2 Findings

The findings of this study are based on the analysis of quantitative data collected through pre-tests and post-tests administered to both the experimental and control groups. The purpose of this analysis was to determine whether the Quantum Teaching Method had a significant effect on the mathematical reasoning skills of Grade IV students. The analysis focused on identifying changes in student performance before and after the intervention and comparing the effectiveness of the Quantum Teaching Method with traditional teaching methods. The findings are presented in alignment with the objectives and research questions of the study.

1. The experimental and control groups began with relatively similar mathematical reasoning skills. The experimental group had a mean pre-test score of 4.16 with a standard deviation of 1.720, while the control group had a mean of 4.16 with a standard

deviation of 1.720. The score range in both groups was between 2 and 9, indicating a comparable distribution. This confirms that the two groups were statistically equivalent at the start of the study, establishing a fair baseline for evaluating the impact of the instructional intervention on table 4.1

2. The pre-test and post-test results of the experimental group. The mean score increased from 4.16 in the pre-test to 15.39 in the post-test, indicating a substantial improvement in students' mathematical reasoning following the implementation of the Quantum Teaching Method on table 4.2

3. The results of a paired samples t-test for the experimental group. The analysis revealed a statistically significant difference between the pre- test and post-test scores, with a mean difference of -11.226, $t(30) = -21.505$, $p < .001$. This confirms that the Quantum Teaching Method had a strong and statistically significant effect on the students' mathematical reasoning skills on table 4.3

4. The pre-test and post-test results for the control group, which was taught through the traditional (Direct Instruction) method. The mean pre-test score was 4.16 with a standard deviation of 1.72, and the mean post-test score increased to 10.68 with a standard deviation of 0.98. This means the control group improved by 6.52 points on average after the teaching period. The smaller standard deviation in the post-test (0.98) compared to the pre-test (1.72) shows that students' scores became more consistent after instruction on table 4.4

5. The results of the paired samples t-test conducted to examine the statistical significance of the control group's pre-test and post-test scores revealed a mean difference of 6.52, with a standard deviation of 2.18 and a 95% confidence interval ranging from 5.84 to 7.20. Although the improvement in the control group's scores was statistically significant, the increase was smaller than that of the experimental group, indicating that the traditional teaching method contributed to some learning gains but was less effective in enhancing students' mathematical reasoning skills on table 4.5

6. The results of the independent samples t-test. The difference between the experimental and control groups' post-test scores was statistically significant, with $t(45.503) = 12.495$, $p < .001$, and a mean difference of 4.71. This indicates that the improvement

observed in the experimental group was not due to chance, but due to the effectiveness of the Quantum Teaching Method on table 4.6

7. The experimental group achieved a significantly higher mean post-test score of 15.39 (SD = 1.856) compared to the control group's mean score of 10.68 (SD = 0.979). This substantial difference indicates that students who received instruction through the Quantum Teaching Method on table 4.7

8. The descriptive statistics for the experimental group's performance across the four reasoning domains. In the pre-test, students scored highest in Comparing (M = 3.23), while performance in Justifying (M= 0.03) and Generalizing (M = 0.00) was minimal. Post-test results showed perfect scores (M= 4.00) in Comparing, Contrasting, and Justifying, and substantial gain in Generalizing (M = 2.84). This indicates strong development in mathematical reasoning following the intervention on table 4.8

9. The results of the paired samples t-test conducted to examine the statistical significance of differences between pre-test and post- test scores in the four core reasoning domains: Comparing, Contrasting, Justifying, and Generalizing. The findings indicate that all four reasoning skills showed statistically significant improvement following the instructional intervention. For the Comparing skill, the improvement was significant with t (30) = -3.760, p =.001, suggesting a meaningful gain in students' ability to identify similarities between mathematical concepts. The Contrasting skill showed a highly significant improvement, with t(30) = -14.124, p = .000, indicating that students greatly enhanced their ability to distinguish differences between concepts. The most substantial change was observed in the Justifying domain, where the test result t (30) = -123.000, p = .000 reflects a dramatic improvement from near- zero pre-test performance to perfect post- test mastery. Finally, the Generalizing skill also improved significantly, with t (30) = -12.737, p = .000, demonstrating students' enhanced ability to extend and apply mathematical patterns and rules. These results confirm that the Quantum Teaching Method led to statistically significant and meaningful gains across all domains of mathematical reasoning on table 4.9

5.3 Discussion

The purpose of this study was to examine the effect of the Quantum Teaching

Method on the development of mathematical reasoning skills among Grade IV elementary school students. The findings of this study demonstrate that students who were taught using the Quantum Teaching Method showed significantly higher improvement in mathematical reasoning compared to those who received instruction through traditional methods. The discussion below interprets these results and relates them to the findings of previous research. The results revealed that both experimental and control groups had nearly. The same level of mathematical reasoning skills at the beginning of the study, as shown by their similar pre- test scores. However, after the intervention, students in the experimental group scored much higher on the post-test compared to the control group. The improvement in the experimental group was statistically significant. This outcome provides clear evidence that the Quantum Teaching Method has a positive effect on developing students' mathematical reasoning abilities, such as comparing quantities, identifying relationships, drawing conclusions, and justifying problem- solving strategies.

These findings are consistent with the results of Jayantika, Parmithi, and Dyanawati (2019), who also found that the Quantum Teaching Learning Model (QTLM) significantly improved student performance and engagement in mathematics by creating meaningful and context-based learning experiences. Similar outcomes were reported by Roviani (2023), who implemented Quantum Teaching in early grades and observed considerable improvement in students' mastery of mathematical concepts and overall test scores. In the current study, a similar pattern of improvement was seen in the experimental group, especially in the ability to explain reasoning and apply mathematical concepts in problem-solving contexts.

Moreover, the present findings align with the research of Pratama and Solehuddin (2019), who demonstrated that the Quantum teaching Model could enhance higher-order thinking skills such as analysis, evaluation, and creative problem-solving. In this study, students in the experimental group were able to apply different strategies to solve problems, justify their methods, and make logical connections between mathematical ideas—abilities closely related to higher-order reasoning. This supports the conclusion that the Quantum Teaching Method is not only effective in improving basic skills but also in developing critical thinking and reasoning abilities in mathematics.

Additionally, the study's findings are supported by Afidin et al. (2022) and Larasati and Baadilla (2023), who both observed increased student participation, motivation, and achievement when the Quantum Teaching model was applied in science education. Though their studies focused on science, the instructional model used—based on the TANDUR cycle (Tumbuhkan, Alami, Namai, Demonstrasikan, Ulangi, Rayakan) was similar to the one used in this research. The current study confirmed that when applied to mathematics instruction, the same structured, emotionally supportive, and interactive environment resulted in better engagement and academic performance. It is also worth noting that students in the experimental group showed stronger retention of learning one week after the intervention. They were able to explain their reasoning, apply mathematical principles to new problems, and retain the concepts taught. These observations mirror the findings of Khozaei et al. (2022), who found that quantum-based learning led to higher long-term retention in nursing education. While the subjects and grade levels differed, the consistency of outcomes suggests that the principles of Quantum Teaching are broadly effective across disciplines and age groups. In contrast, the control group in this study, which was taught using traditional methods, showed limited improvement and continued to struggle with reasoning-based tasks. This confirms earlier concerns raised by Ersoy and Bal-İncebacak (2017) and Napitupulu (2017), who reported that traditional teaching approaches often fail to develop deep mathematical understanding and reasoning in students. These studies emphasize the importance of teaching methods that actively involve students in the learning process and encourage them to think critically and solve problems independently.

In summary, the findings of this study are in strong agreement with previous national and international research. The positive impact of the Quantum Teaching Method observed in this study reinforces the view that student-centered, emotionally engaging, and brain-based instructional models are highly effective in enhancing mathematical reasoning skills. These results suggest that integrating such methods into mathematics classrooms at the elementary level can lead to substantial academic benefits and support students in becoming confident, reflective, and skilled mathematical thinkers.

5.4 Conclusions

Based on the analysis of quantitative data, classroom observations, and comparison with previous research, conclusions are based on finding regarding the effect of the Quantum Teaching Method on mathematical reasoning skills at the elementary school level.

1. Finding 1 showed that the experimental and control groups had similar levels of

mathematical reasoning skills before the intervention, as evidenced by their comparable pre-test mean scores. Therefore, it is concluded that both groups started from an equivalent baseline, allowing for a fair and unbiased evaluation of the instructional impact.

2. Finding 2 showed that the experimental group demonstrated a significant improvement in post-test scores after being taught through the Quantum Teaching Method. It is concluded that the Quantum Teaching Method is highly effective in enhancing mathematical reasoning skills among Grade IV students.
3. Finding 3 confirmed through a paired samples t-test that the improvement observed in the experimental group was statistically significant. Thus, it is concluded that the observed gains in mathematical reasoning were not due to chance, but were a direct result of the Quantum Teaching Method.
4. Finding 4 showed that the results show that students in the control group, who were taught through the traditional method, improved their mathematical reasoning skills. Their average score increased from 4.16 to 10.68, which means they learned and performed better after the lessons. The smaller standard deviation in the post-test (0.98) shows that students' scores became more similar and consistent after teaching.
5. Finding 5 showed that the t-test results confirmed that the control group's improvement was statistically significant, meaning their progress was real and not by chance. However, the amount of improvement was less than the experimental group's gain. This shows that while the traditional method helped students improve, it was not as effective as the Quantum Teaching Method in building strong mathematical reasoning skills.
6. Finding 6 showed that the experimental group outperformed the control group in the post- test, with a much higher mean score. This leads to the conclusion that students taught through the Quantum Teaching Method achieved better learning outcomes compared to those taught through traditional methods.
7. Finding 5 revealed a statistically significant difference between the post-test scores of the experimental and control groups, as confirmed by an independent samples t-test. Therefore, it is concluded that the Quantum Teaching Method is more effective than traditional instruction in improving students' mathematical reasoning.

8. Finding 6 showed significant improvement across the four-core reasoning domain comparing, contrasting, justifying, and generalizing—in the experimental group. It is concluded that the Quantum Teaching Method successfully develops students' higher-order thinking and mathematical reasoning abilities in multiple cognitive areas.
9. Finding 7 provided evidence through paired samples t-tests that the gains in all four reasoning domains were statistically significant, particularly in justifying and generalizing skills. Hence, it is concluded that the Quantum Teaching Method leads not only to general academic improvement but also to deep conceptual understanding and the ability to explain and extend mathematical thinking.

5.5 Recommendations

Based on the findings and conclusions of this study, following practical and research-based recommendations are proposed for teachers, school leaders, curriculum developers, and future researchers. These recommendations aim to improve mathematics teaching and learning at the elementary level by incorporating effective strategies such as the Quantum Teaching Method.

1. Based on conclusion 1 The Quantum Teaching Method may be adopted in primary mathematics classrooms, as it led to a statistically significant improvement in students' reasoning abilities and overall performance. The structured approach provided through this method created a learning environment that was engaging, student-centered, and conducive to higher- order thinking.
2. Based on conclusion 2 Lesson planning in mathematics instruction requires alignment with the EEL DR C framework used in the Quantum Teaching Method. The consistent application of its six phases Enroll, Experience, Label, Demonstrate, Review, and Celebrate ensures active learner participation and deeper cognitive processing, which were strongly linked to the improvement observed in the experimental group.
3. Based on conclusion 3 Assessments in elementary mathematics may include tasks that focus on reasoning skills such as comparing, contrasting, justifying, and generalizing. The study revealed that students improved significantly in these areas when such domains were targeted directly. Regular exposure to reasoning-focused tasks allows students to move beyond memorization and engage with mathematical

concepts at a deeper level.

4. Based on conclusion 4Traditional teaching methods can help improve students' basic understanding of mathematics, but the improvement is limited compared to modern approaches. Therefore, it is recommended that teachers integrate active and student-centered strategies such as group discussions, hands-on activities, and visual aids—into traditional lessons. This combination can make learning more engaging and help students strengthen their reasoning and problem-solving skills.
5. Based on conclusion 5 the traditional method produced smaller learning gains than the Quantum Teaching Method, it is recommended that schools and teachers gradually adopt the Quantum Teaching approach in mathematics classrooms. Training and workshops should be arranged to help teachers understand how to apply this method effectively, ensuring that instruction focuses on reasoning development, conceptual understanding, and student participation**.**
6. Based on conclusion 6 Teacher training programs may include focused instruction on student-centered teaching strategies. The control group, which received traditional instruction, showed comparatively lower improvement. This suggests that teachers need access to professional development opportunities that equip them with techniques for engaging students through dialogue, exploration, and reasoning.
7. Based on conclusion 5 Students may be grouped based on prior performance when implementing reasoning- intensive instruction. While random assignment was used in this research setting, applying performance-based grouping in real classrooms allows teachers to differentiate instruction effectively and address the varying needs of learners during complex problem-solving tasks.
8. Based on conclusion 6 Reasoning-based instruction may be introduced in earlier primary grades. The initial lack of ability in justifying and generalizing observed in the pre-test data highlights the importance of early exposure. Developing reasoning skills from an earlier stage allows students to build a stronger foundation and prepares them to handle more abstract concepts in later years.

5.5.1 Recommendations for Future Studies

Although the study has shown that the Quantum Teaching Method significantly improves mathematical reasoning skills among Grade IV students, it was limited in scope, context, and duration. Therefore, several areas are recommended for further research to build upon and extend the findings of this study:

1. Future researchers may conduct this study with a larger sample size across multiple schools, districts, and regions. A broader population would increase the generalizability of the results and provide a clearer picture of the Quantum Teaching Method's impact in diverse educational settings, including both urban and rural contexts.
2. Conducting studies at different grade levels and across various subjects, such as science, English, or social studies, to examine whether the benefits of the Quantum Teaching Method observed in mathematics also apply to other areas of learning. This will help determine the versatility of the method in promoting reasoning and conceptual understanding across the curriculum.
3. Longitudinal research is recommended to evaluate the long-term effects of Quantum Teaching on student learning and retention. In this study, retention was assessed informally shortly after the post-test. Future studies may use a delayed post-test conducted several months after the intervention to assess the sustainability of reasoning skills over time.
4. Qualitative and mixed-methods studies may provide deeper insights into students' and teachers' experiences with the Quantum Teaching Method. Such studies may include interviews, classroom observations, and reflective journals to explore how the method influences student motivation, engagement, and attitudes toward mathematics.
5. Future studies exploring the role of teacher training and professional development in the successful implementation of Quantum Teaching. Investigating how teacher beliefs, instructional skills, and classroom management practices influence the outcomes of Quantum Teaching can provide valuable recommendations for educator preparation programs.
6. Research focusing on the integration of digital tools or technology with Quantum Teaching, examining whether educational apps, virtual manipulatives, or interactive media enhance or hinder the application of the TANDUR framework in contemporary classrooms. Cross-cultural or international comparative studies are

also recommended, especially in countries with different educational systems or cultural attitudes toward teaching and learning. This help assess how adaptable and effective the Quantum Teaching Method is across various socio-cultural settings.

7. Future research investigating the cost-effectiveness and feasibility of scaling the Quantum Teaching Method in government schools, especially those with limited resources. Exploring affordable adaptations of the method will help inform policy and curriculum reforms.
8. Study may be replicated in a variety of educational settings, including private schools, rural areas, and schools with different student populations. Expanding the research to diverse contexts will help confirm the broader applicability and reliability of the Quantum Teaching Method and support evidence-based educational planning across school systems.

In conclusion, while this study provides strong support for the use of the Quantum Teaching Method in improving mathematical reasoning at the elementary level, further research is essential to deepen our understanding of its broader impact, refine its implementation strategies, and inform future educational practices.

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APPENDICES

7.1 APPENDIX -A lesson plan for experimental group

Unit 4: The Factor Forest and Multiple Mountains Adventure

Grade: 4

Time per lesson: 50 minutes

Model: EEL DR C (Enroll, Experience, Label, Demonstrate, Review, Celebrate)

Lesson Plan 1: Divisibility by 2

Topic: Divisibility Rule for 2

Objectives (Reasoning Skills):

1. Comparing: Students will compare even and odd numbers using concrete examples.
2. Contrasting: Students will identify differences between numbers that are divisible by 2 and those that are not.
3. Generalizing: Students will construct the rule for divisibility by 2 from observed patterns.
4. Justifying: Students will explain their reasoning for classifying a number as divisible or not divisible by 2.

QTM Step	Time	Teacher Activity	Student Activity
Enroll	5 Mins	Use real socks/shoes as props. Ask: "If you have 3 shoes, can you pair them evenly?" Introduce even/odd using storytelling and relatable daily-life scenario.	Observe teacher, reflect on own experience (e.g. odd socks), and respond to questions. Begin thinking about what makes a number even.
Experience	12 Mins	Ask each student to think of and write one number between 1–50 that they believe is divisible by 2. Then ask: "Can you divide your number by 2 with no remainder?" Students who say yes raise their hands. Ask those who say no: "What makes your number not divisible?"	Students write their own number, test it for divisibility, and raise hands if divisible. If not, explain why. Engage actively and listen to peers' explanations.

Label	10 Mins	Write rule: "A number is divisible by 2 if it ends in 0, 2, 4, 6, or 8." Use board examples like 12, 26, 47. Highlight last	Copy the rule, underline last digits of examples. Use their previous example to confirm
		digits. Discuss common mistakes students made in previous step.	or correct their classification. Ask clarifying questions.
Demonstrate	10 Mins	Demonstrate divisibility with visual aids (blocks or board diagrams). Show how 24 is evenly split; explain why 27 is not. Ask a few students to come and try with new numbers like 36 or 19.	Observe, follow demonstration. Volunteers solve and explain new examples on the board. Others offer feedback or clap for correct answers.
Review	8 Mins	Play "Clap if Even" game. Read numbers aloud; students clap if divisible by 2.	Actively participate in game.
Celebrate	5 Mins	Praise effort and improvement. Award "Even Number Expert" stickers. Lead class chant: "2, 4, 6, 8 – Even is Great!"	Smile, celebrate their learning, and proudly accept stickers. Reflect on what they understood best.

Lesson Plan 2: Divisibility by 3

Topic: Divisibility Rule for 3
Objectives (Reasoning Skills):

1. Comparing: Students will compare numbers whose digits have different sums.
2. Contrasting: Students will distinguish between numbers that are and are not divisible by 3.
3. Generalizing: Students will use the sum of digits to identify the rule for divisibility by 3.
4. Justifying: Students will explain their reasoning behind why a number is or isn't divisible by 3.

QTM Step	Time	Teacher Activity	Student Activity
Enroll	5 mins	Tell a short story: "Ali is packing pencil sets in groups of 3. If he has 15 pencils, can he make complete sets?" Use props or board drawing for illustration.	Listen to the story, respond to questions, and begin thinking about equal grouping by 3.

QTM Step	Time	Teacher Activity	Student Activity
Experience	12 mins	Write 10 numbers on the board (e.g., 9, 13, 18, 21). Ask each student to choose a number, find the sum of its digits, and decide if divisible by 3. Ask them to place ✓ (yes) or ✗ (no) next to it and explain.	Choose a number, compute digit sum, and decide divisibility. Share answers on the board and explain their thinking aloud.
Label	10 mins	Write on board: "A number is divisible by 3 if the sum of its digits is divisible by 3." Show examples (e.g., 12 → 1+2=3 ✓, 14 → 1+4=5 ✗).	Copy the rule into notebooks, underline important digits, and test the rule with 2–3 of their own examples.
Demonstrate	10 mins	Use base-10 blocks or drawings to show why 27 is divisible and 35 is not. Invite volunteers to demonstrate and justify new numbers like 36 or 20.	Observe teacher's demonstration. Volunteers show examples on the board and explain their reasoning to the class.
Review	8 mins	Play "Thumbs Up/Thumbs Down": Teacher calls a number; students respond based on whether it's divisible by 3. Then give a short worksheet to complete.	Participate in review game actively. Complete 5-question worksheet and check answers with teacher feedback.
Celebrate	5 mins	Praise effort. Give "Triple Checker" stickers. End with chant: "3, 6, 9 – We divide just fine!" Ask: "What did you learn about 3 today?"	Receive praise and stickers. Reflect and share something they found interesting about divisibility by 3.

Lesson Plan 3: Divisibility by 5

Topic: Divisibility Rule for 5

Objectives (Reasoning Skills):

1. Comparing: Students will compare numbers ending in 0 or 5 to identify divisibility.
2. Contrasting: Students will differentiate between numbers that are divisible by 5 and those that are not.
3. Generalizing: Students will describe a rule for recognizing numbers divisible by 5.
4. Justifying: Students will explain how they know a number is divisible by 5.

QTM Step	Time	Teacher Activity	Student Activity
Enroll	5 mins	Begin with a story: "Saleem has Rs. 25, and each pen costs Rs. 5. How many pens can he buy?" Use real or drawn coins for engagement.	Listen, respond, and start thinking about 5s in daily life.
Experience	12 mins	Display numbers 10–50 on board. Students come one by one to circle numbers that end in 0 or 5. Ask: "Can this number be divided by 5?"	Students come to board, circle a number, and state why it is or isn't divisible by 5.
Label	10 mins	Write: "A number is divisible by 5 if it ends in 0 or 5." Show examples: 25 ✓, 32 ✗.	Copy rule and apply it to numbers in their notebooks.
Demonstrate	10 mins	Use number line or real money (Rs. 5 notes/coins). Divide 30, 35, etc., to demonstrate exact division.	Watch, then solve and explain examples like 40, 22.
Review	8 mins	"Stand if Divisible": Read numbers aloud. Students stand if divisible by 5. Give a worksheet (5 MCQs).	Respond to game, complete and check worksheet.
Celebrate	5 mins	Award "High Five Hero" stickers. Ask: "What did you notice about numbers ending in 0 or 5?"	Join in chant: "5, 10, 15 — count with me!" Reflect and share key ideas.

Lesson Plan 4: Divisibility by 10

Topic: Divisibility Rule for 10

Objectives (Reasoning Skills):

2. Contrasting: Students will identify which numbers are divisible by 10 and which are not.
3. Generalizing: Students will state the rule for divisibility by 10.
4. Justifying: Students will explain their reasoning for determining divisibility by 10.

QTM Step	Time	Teacher Activity	Student Activity
Enroll	5 mins	Begin with a real-life question: "Ali packs 10 pencils in a box. If he has 70 pencils, how many boxes can he fill?"	Listen, guess, and discuss how 10 fits into daily use.
Experience	12 mins	Write numbers 10–100 on the board. Ask each student to underline numbers ending in 0 and say if divisible by 10.	Underline and explain choices. Respond aloud.
Label	10 mins	Write: "A number is divisible by 10 if it ends in 0." Show examples (20, 50 ✓; 53, 77 ✗).	Write rule in notebooks. Suggest more examples and test.
Demonstrate	10 mins	Show that 60 ÷ 10 = 6 using place value or groups of 10. Ask a few students to explain 90, 42, 100.	Observe and explain sample numbers. Respond whether they are divisible and why.
Review	8 mins	Game: "Hands Up if Yes" – call a number, students raise hand if divisible. Then give a mini assessment (5 items).	Play game, finish worksheet, and review answers.
Celebrate	5 mins	Award "Perfect 10 Champion" cards. Ask for reflections: "What numbers are always divisible by 10?"	Join chant: "10, 20, 30 — we know it early!" Share a fun fact about 10s.

Lesson Plan 5: Introduction to Factors

Topic: Understanding What Factors Are

Objectives

1. **Comparing:** Students will compare factor counts of different numbers.
2. **Contrasting:** Students will distinguish between numbers that have more vs. fewer factors.
3. **Generalizing:** Students will identify patterns among factor pairs.
4. **Justifying:** Students will explain how they found the factor pairs of a number.

QTM Step	Time	Teacher Activity	Student Activity
Enroll	5 mins	Show 12 pencils. Ask: "In how many ways can I group these equally?" Use 2s, 3s, 4s, 6s as examples.	Suggest different equal groups. Observe and respond with possible combinations.
Experience	12 mins	Write numbers 6, 8, 10, and 12 on the board. Ask students to find all possible factor pairs. Write them on board with arrows.	Identify factor pairs for each number. Say them aloud and compare their factor counts.
Label	10 mins	Write: "A factor is a number that divides another number exactly." Give examples and non-examples.	Copy the definition. Underline key words. Add examples from the board to notebooks.
Demonstrate	10 mins	Use place value blocks or circles to show 6 = 1×6, 2×3. Repeat for 10. Highlight how the order of multiplication creates pairs.	Observe and then demonstrate with teacher guidance. Try with their own example (e.g. 9 or 15).
Review	8 mins	Ask: "What are the factors of 12?" "What about 7?" Give a 5-question worksheet with different numbers to factorize.	Answer questions aloud. Solve the worksheet and explain answers when asked.
Celebrate	5 mins	Applaud all efforts. Give out "Factor Star" cards. End with a chant: "Divide it right, factor it tight!"	Join in celebration. Reflect on what they learned and share how they found factor pairs.

Lesson Plan 6: Exploring Factor Patterns

Objectives

1. **Comparing:** Students will compare factor sets for numbers 11–20.
2. **Contrasting:** Students will distinguish between numbers with only two factors vs. many.
3. **Generalizing:** Students will identify a pattern for odd/even numbers and their factors.
4. **Justifying:** Students will explain why a number has the specific number of factors it does.

QTM Step	Time	Teacher Activity	Student Activity
Enroll	5 mins	Ask: "Why do you think 13 can only be divided by 1 and 13?" Prompt thinking about limited groupings.	Predict and respond with reasoning. Think of other similar numbers.
Experience	12 mins	Write numbers 11–20 on the board. Ask students to test them for factors using division or multiplication facts.	Use skip counting, multiplication tables, and division to list all factor pairs of each number.
Label	10 mins	Write: "Some numbers have only two factors — 1 and itself." Define these as special. Re-explain factor with examples.	Copy the definition and examples. Mark numbers that have only two factors vs. those with more.
Demonstrate	10 mins	Show difference using a T-chart: 13 = only 1×13; 12 = 1×12, 2×6, 3×4. Circle the extra pairs. Ask what they observe.	Compare and discuss factor counts. Explain why they think a number is limited in factor options.
Review	8 mins	Oral quiz: "Which has more factors — 14 or 16?" Then give worksheet: list all factors of given numbers and underline repeated ones.	Answer aloud. Complete worksheet. Discuss with teacher and peers if any errors occur.
Celebrate	5 mins	Award "Factor Thinker" cards. Lead chant: "Find the pair, show you care — Factors!"	Cheer, reflect on mistakes and successes, and clap for strong justifications shared during review.

Lesson Plan 7: Multiples

Objectives

1. **Comparing:** Students will compare lists of multiples for different numbers.
2. **Contrasting:** Students will distinguish between a factor and a multiple.
3. **Generalizing:** Students will identify patterns in multiples.
4. **Justifying:** Students will explain how and why a number is a multiple of another.

QTM Step	Time	Teacher Activity	Student Activity
Enroll	5 mins	Show 3 bundles of 5 pencils. Ask: "How many pencils total?" Repeat with 4 bundles.	Predict and count pencils. Begin connecting multiplication and multiples.
Experience	12 mins	Write a number (e.g., 4) on the board. Ask students to skip count and list first 5 multiples. Repeat for 5 and 6.	Skip count aloud and write the multiples. Observe and compare with classmates.
Label	10 mins	Write: "A multiple is the product of a number and a whole number." Use visual number line.	Copy definition. Generate 3 examples of their own in notebooks.
Demonstrate	10 mins	Draw number line. Show $5 \times 1 = 5$, $5 \times 2 = 10$, etc. Discuss how multiples grow in consistent steps.	Follow along and create their own list of multiples for 3 or 7.
Review	8 mins	Play "Multiple Relay": Teacher says a number; students write 3 multiples quickly. Give a 5-question worksheet.	Join the game. Complete worksheet. Check answers in class discussion.
Celebrate	5 mins	Praise effort. Award "Multiple Master" stickers. Chant: "3, 6, 9 — Multiples shine!"	Join chant, share one new multiple they remember confidently.

Lesson Plan 8: Multiples

Objectives

1. **Comparing:** Students will compare multiples of two numbers.
2. **Contrasting:** Students will identify common multiples in lists.
3. **Generalizing:** Students will find and explain the Least Common Multiple (LCM).
4. **Justifying:** Students will explain how to find a common multiple using skip counting or multiplication tables.

QTM Step	Time	Teacher Activity	Student Activity
Enroll	5 mins	Ask: "Ali visits school every 4 days, Sara every 6 days — when will they both be at school again?"	Think and share guesses. Link real-life to shared multiples.
Experience	12 mins	Write multiples of 4 and 6 side-by-side on board. Ask students to identify overlapping numbers.	Copy lists and highlight common multiples (e.g., 12, 24).
Label	10 mins	Define: "Common multiples are in both lists." Introduce concept of Least Common Multiple (LCM).	Copy definition and try examples with 2 numbers (e.g., 3 and 5).
Demonstrate	10 mins	Show Venn diagram or list method for 3 and 4. Circle the common multiples. Discuss smallest one.	Create their own chart for a new pair (e.g., 2 and 6). Explain LCM aloud.
Review	8 mins	Play "Common Multiple Match": Say a pair (e.g., 3 & 4); students call out LCM. Then solve 5-question sheet.	Participate in the game. Complete worksheet and check together.
Celebrate	5 mins	Award "Common Number Pro" badge. Reflect: "Which numbers were easiest to find?"	Join chant: "Common ground, we all have found!" Share what helped them learn LCM.

Lesson Plan 9: Prime Numbers Objectives

1. **Comparing:** Students will compare numbers with only two factors to those with more.
2. **Contrasting:** Students will distinguish between prime and non-prime numbers.

3. **Generalizing:** Students will identify patterns in prime numbers from 1 to 20.
4. **Justifying:** Students will explain why a number is classified as prime.

QTM Step	Time	Teacher Activity	Student Activity
Enroll	5 mins	Ask: "If I can only arrange 7 chairs in 1 row or 7 rows of 1, is 7 special?" Introduce concept of limited factors.	Think and share how some numbers have very few ways to be grouped.
Experience	12 mins	Hand out numbers 1–20. Ask students to test if each number can be grouped in more than 2 ways.	Use dots or counters to test divisions. Record how many groupings are possible.
Label	10 mins	Write: "A prime number has exactly two factors — 1 and itself." Provide a prime number chart from 1–20.	Copy rule. Highlight or circle all prime numbers in chart.
Demonstrate	10 mins	Use examples (2, 3, 5, 7) vs (4, 6, 8) to show factor pairs. Use visuals or array drawings.	Create factor pairs or groupings. Identify and explain which numbers are prime.
Review	8 mins	Game: "Prime or Not?" – green card for prime, red card for not prime. Then give worksheet: sort and list numbers.	Play card game. Solve and discuss worksheet.
Celebrate	5 mins	Award "Prime Time Genius" title. Chant: "One and itself – that's the prime wealth!"	Join chant and reflect on one new prime number they learned.

Lesson Plan 10: Prime Numbers

Objectives (Reasoning Skills):

1. **Comparing:** Students will compare prime vs composite numbers up to 50.
2. **Contrasting:** Students will classify numbers based on factor count.
3. **Generalizing:** Students will find prime patterns using the sieve method.
4. **Justifying:** Students will explain why a number is or is not prime.

QTM Step	Time	Teacher Activity	Student Activity
Enroll	5 mins	Give riddle: "I am more than 10, less than 20, and only divisible by 1 and myself — who am I?"	Solve riddle and guess other prime numbers.
Experience	12 mins	Hand out number grid (1–50). Ask students to mark all numbers divisible by 2, 3, 5, etc., to find the primes left.	Apply Sieve of Eratosthenes. Cross out non-primes and circle remaining primes.
Label	10 mins	Revisit definition of prime. Reinforce idea using sieve method. Compare patterns with multiples.	Copy definition. Identify and color-code new prime numbers on chart.
Demonstrate	10 mins	Choose examples (29 vs 30). Ask students to try dividing them and explain why only one is prime.	Work in pairs or solo to try factor pairs and explain why numbers are or aren't prime.
Review	8 mins	Game: "Prime Stand-Up" – If teacher says a prime, students stand. Otherwise, sit. Then complete worksheet.	Play game and solve classification worksheet (prime/composite).
Celebrate	5 mins	Award "Prime Detective" badges. Lead chant: "Divide it twice — and that's precise!"	Chant together and reflect on which prime surprised them most.

Lesson Plan 11: Introduction to Composite Numbers

Objectives

1. **Comparing:** Students will compare composite numbers with prime numbers.
2. **Contrasting:** Students will differentiate between composite and prime numbers based on number of factors.
3. **Generalizing:** Students will recognize patterns among composite numbers.
4. **Justifying:** Students will explain why a number is composite using factor pairs.

QTM Step	Time	Teacher Activity	Student Activity
Enroll	5 mins	Ask: “Can we group 12 pencils in more than one way?” Show 1×12, 2×6, 3×4. Ask: “Is 12 special compared to 7?”	Observe groupings and respond. Share other numbers that can be grouped more than two ways.
Experience	12 mins	Write numbers 4–20 on board. Ask students to list factor pairs. Emphasize numbers with 3 or more factor pairs.	List factor pairs for each number. Circle those with more than 2 factors.
Label	10 mins	Define: “A composite number has more than two factors.” Give examples: 4, 6, 8, 9, 10. Contrast with prime numbers.	Copy definition. Label numbers from experience step as “composite” or “not composite.”
Demonstrate	10 mins	Use array model or number line to show composite structure of 6 and 9. Invite students to show 10 or 12.	Create arrays, groupings, or draw number lines. Discuss why the number is composite.
Review	8 mins	“Composite Clap Game” – Clap when number is composite. Read out 10 numbers. Then assign worksheet: mark all composite numbers.	Participate in game. Complete worksheet and explain why numbers are composite.
Celebrate	5 mins	Give out “Composite Hero” badge. End with chant: “More than two, composite is true!”	Join chant, share a composite number they remember and how they found its factors.

Lesson Plan 12: Exploring Composite Numbers

Objectives

1. **Comparing:** Students will compare composite numbers by factor count.
2. **Contrasting:** Students will identify numbers that are not composite and explain why.
3. **Generalizing:** Students will build rules to spot composites quickly (e.g.,

even numbers >2).**Justifying:** Students will prove a number is composite using factor trees or repeated grouping.

QTM Step	Time	Teacher Activity	Student Activity
Enroll	5 mins	Show number cards (e.g., 15 and 17). Ask: "Which one can be grouped in more than one way?" Reinforce composite idea.	Choose between options and give reasons. Begin recalling earlier lesson ideas.
Experience	12 mins	Give each student a number (21–30). Ask them to use skip counting or multiplication facts to find all factor pairs.	Identify and write all factor pairs. Share results aloud.
Label	10 mins	Review: "Composite numbers have more than two factors." Introduce strategy: If it's even and >2, or product of two small numbers = composite.	Copy rule. Apply it to new examples. Create own composite list from 1–50.
Demonstrate	10 mins	Make factor trees for 18, 24, and 30. Highlight how many branches come out. Compare to prime tree (e.g., 19).	Complete a factor tree in notebook. Compare it with peer or board example.
Review	8 mins	Game: "Composite or Prime?" – Show a number. Students flash card with C (composite) or P (prime). Then complete worksheet of 10 numbers.	Play game and mark responses. Fill out worksheet. Ask questions if unsure.
Celebrate	5 mins	Award "Composite Star" ribbon. Ask: "How many composites did you discover today?"	Share final thoughts and chant: "Group, divide, and multiply — that's how composite numbers qualify!"

Lesson Plan 13: Understanding Improper Fractions)

Objectives

1. Comparing: Students will compare improper fractions to whole numbers.
2. Contrasting: Students will distinguish between proper and improper fractions.
3. Generalizing: Students will identify patterns in improper fractions.
4. Justifying: Students will explain how an improper fraction represents more than one whole.

QTM Step	Time	Teacher Activity	Student Activity
Enroll	5 mins	Show 7 half-sheet paper strips. Ask: "How many full papers is this?"	Observe, respond (3 wholes and 1 half), think about what makes this fraction improper.
Experience	12 mins	Use fraction bars to model 7/2, 9/4, and 11/5. Guide students in visualizing parts more than one whole.	Draw or use strips to model improper fractions.
Label	10 mins	Define: "Improper fractions have numerators greater than denominators." Use chart to list examples.	Copy definition and chart. Add at least 2 of their own examples.
Demonstrate	10 mins	Solve: "If you ate 5 halves of a sandwich, how many whole sandwiches did you eat?" (Answer: 2 1/2 or 5/2).	Answer and model new examples. Discuss how many wholes fit into their fractions.
Review	8 mins	"Is it Improper?" Show 5 fractions; students vote by thumbs up/down.	Justify their vote and fix errors with support.
Celebrate	5 mins	Award "Top-Heavy Hero" badges. Chant: "Numerator tall, improper for all!"	Join chant and reflect on one new example they learned.

Lesson Plan 14: Converting Improper to Mixed Numbers

Objectives

1. Comparing: Compare improper and mixed forms.
2. Contrasting: Distinguish between their structure and interpretation.
3. Generalizing: Learn rule of division to convert.
4. Justifying: Explain step-by-step using visuals or division.

QTM Step	Time	Teacher Activity	Student Activity
Enroll	5 mins	Ask: "If you have 11 slices and 4 slices make a pizza, how many pizzas do you have?"	Guess: "2 pizzas and 3 slices." Start linking to 11/4 = 2 3/4.
Experience	12 mins	Model 9 ÷ 4 → 2 R1. Then: 9/4 = 2 1/4. Show process on board with visuals.	Try with 7/3 and 10/3 in notebooks. Share answers.
Label	10 mins	Write rule: Divide numerator ÷ denominator. Quotient = whole, remainder = new numerator. Keep denominator the same.	Copy rule and apply it to 13/5 and 11/2.
Demonstrate	10 mins	Students come solve 12/5, 14/6 at board and explain their steps. Discuss remainder placement.	Work in pairs or solo, present answer with explanation.
Review	8 mins	Worksheet: 4 conversions. Peer check in pairs.	Complete and correct. Ask if unsure.
Celebrate	5 mins	Award "Fraction Flipper" badge. Chant: "Divide it down, then mix it around!"	Join chant and reflect on easiest conversion.

Lesson Plan 15: Converting Mixed Numbers to Improper (Day 3)

Objectives

1. Comparing: Compare parts of mixed numbers to improper form.
2. Contrasting: Distinguish between whole part and fractional part.
3. Generalizing: Use the formula: (Whole × Denominator) + Numerator.
4. Justifying: Explain the conversion process clearly.

QTM Step	Time	Teacher Activity	Student Activity
Enroll	5 mins	Ask: "If you ate 3 whole pizzas and 1/4 of another, how many fourths did you eat?"	Predict: "13/4." Visualize situation.
Experience	12 mins	Model 2 1/4 → (2×4)+1 = 9/4. Show visual slices on board.	Solve 1 2/3 and 3 1/2 with teacher. Write and explain.
Label	10 mins	Write rule: (Whole × Denominator) + Numerator = New numerator. Denominator remains the same.	Copy rule. Practice rule with 2 examples.
Demonstrate	10 mins	Convert 4 2/5 and 3 3/4. Ask students why this works.	Come to board, solve, explain to peers.
Review	8 mins	Match Game: Mix of 5 mixed numbers and 5 improper. Students pair them correctly.	Play and check results. Peer explanation.
Celebrate	5 mins	Award "Conversion Champ" badge. Chant: "Whole times bottom, then add the top!"	Join chant and clap for conversions done well.

Lesson Plan 13: Understanding Improper Fractions

Objectives

1. **Comparing:** Compare improper fractions to whole numbers.
2. **Contrasting:** Differentiate between proper and improper fractions.
3. **Generalizing:** Identify visual patterns in improper fractions.
4. **Justifying:** Explain how an improper fraction shows more than one whole.

QTM Step	Time	Teacher Activity	Student Activity
Enroll	5 mins	Show 7 half-circle paper models. Ask: "How many full circles is this?" (Relate to example 7/2 in textbook)	Respond: "3 full and 1 half." Begin thinking about how improper fractions show more than one whole.
Experience	12 mins	Display visual bars for 9/4 and 11/4 (like textbook). Ask: "How many wholes are in 9/4? 11/4?"	Use visual aids to count wholes and parts. Color or circle bars to find wholes.

QTM Step	Time	Teacher Activity	Student Activity
Label	10 mins	Define: "An improper fraction has a numerator greater than or equal to the denominator." Show textbook example of 7/2 and 9/4.	Copy the definition. Write 2 new examples of improper fractions from textbook.
Demonstrate	10 mins	Use counters to show why 9/4 = more than 2 wholes. Use textbook visual steps. Ask: "What happens if the top number is equal to or greater than the bottom?"	Try same with 13/5 using objects or diagrams. Count and share.
Review	8 mins	"Thumbs Up if Improper" Game: Show 5 textbook fractions (e.g., 2/3, 7/2, 8/4, 3/5, 9/3). Ask students to vote.	Raise thumbs and explain. Correct misconceptions as a class.
Celebrate	5 mins	Award "Improper Hero" stickers. Chant: "Top too big? Improper – that's it!"	Join chant. Reflect on one improper fraction they remember.

Lesson Plan 14: Converting Improper Fractions to Mixed Numbers

Objectives

1. **Comparing:** Compare improper fractions with their equivalent mixed forms.
2. **Contrasting:** Identify differences in format and meaning.
3. **Generalizing:** Develop rules for converting.
4. **Justifying:** Explain each step using division.

QTM Step	Time	Teacher Activity	Student Activity
Enroll	5 mins	Use pizza slices: "If you have 11 slices and 4 make a pizza, how many pizzas?" Use 11/4 example from textbook.	Predict: "2 pizzas and 3 slices." Link to 2 3/4.

Experience	12 mins	Use board to solve 9 ÷ 4 = 2 R1. Show 9/4 = 2 1/4 (textbook). Use same logic to model 13/5 = 2 3/5.	Work out 7/3 and 10/3 with help. Represent on number lines or with groups.
Label	10 mins	Write rule: Divide numerator ÷ denominator. Quotient = whole, remainder = numerator. Show examples: 11/4 = 2 3/4.	Copy rule and test it on 15/4 or 8/3. Use class visuals if needed.
QTM Step	**Time**	**Teacher Activity**	**Student Activity**
Demonstrate	10 mins	Invite students to solve 13/5, 14/6 on board. Ask: "Why is that the whole number? Why this numerator?"	Explain steps. Peers listen and suggest corrections.
Review	8 mins	Convert 5 improper fractions to mixed. Use 2 from the book, 3 from practice set.	Discuss answers in pairs or group.
Celebrate	5 mins	Award "Fraction Flipper" badge. Chant: "Top to whole, part to side – now the mixed is multiplied!"	Join chant and share one tricky question and how they solved it.

Lesson Plan 15: Converting Mixed Numbers to Improper Fractions

Objectives

1. **Comparing:** Compare values before and after conversion.
2. **Contrasting:** Identify whole vs. fractional parts.
3. **Generalizing:** Use multiplication + addition rule.
4. **Justifying:** Explain the conversion steps using operations.

QTM Step	Time	Teacher Activity	Student Activity
Enroll	5 mins	Ask: "If you eat 2 whole pizzas and 1 out of 4 slices from another, how many total slices?" Use 2 1/4 = 9/4.	Predict, calculate: "2×4 + 1 = 9." Write as 9/4.

Experience	12 mins	Model example: 3 1/2 → 7/2. Use textbook visuals and shaded bars. Use conversion formula.	Apply steps for 4 2/5 and 2 3/4 using book method.
Label	10 mins	Rule: Multiply whole × denominator + numerator = new numerator. Keep denominator.	Copy rule. Test with 5 1/6 → (5×6)+1 = 31/6.
Demonstrate	10 mins	Ask 2 students to solve 3 2/5 and 1 3/4 on board. Explain full method.	Solve in front of class. Peers correct or confirm answer.
QTM Step	**Time**	**Teacher Activity**	**Student Activity**
Review	8 mins	Match 5 mixed numbers to improper form. Use examples like 2 2/3 = 8/3, 1 3/4 = 7/4.	Match and explain at least one pair.
Celebrate	5 mins	Give "Conversion Master" award. Chant: "Whole times bottom, then add the top!"	Reflect and celebrate with classmates.

Lesson Plan 16: Comparing Fractions with Same Denominator

Objectives (Reasoning Skills):

1. **Comparing:** Compare fractions with the same denominator.
2. **Contrasting:** Differentiate between greater and smaller numerators.
3. **Generalizing:** Construct a rule for comparing like-denominator fractions.
4. **Justifying:** Explain why one fraction is greater than another using visuals or reasoning.

QTM Step	Time	Teacher Activity	Student Activity
Enroll	5 mins	Use two equal bars: shade 3/5 of one, 4/5 of the other. Ask: "Which shows more?" Relate to sharing chocolate.	Answer and justify: "4/5 is more because it has more shaded parts."

Experience	12 mins	Show textbook example: 2/5 vs 4/5. Use fraction strips. Ask students: "If the denominator is same, what do you look at?"	Use paper strips to model 2/5 and 4/5. Explain which is more and why.
Label	10 mins	Write: "When denominators are the same, compare numerators. The bigger numerator means a bigger fraction." Show 5/8 > 2/8.	Copy rule and example into notebook. Try comparing: 1/6 vs 4/6, 3/10 vs 7/10.
Demonstrate	10 mins	Ask students to order 1/7, 6/7, 3/7 on the board. Use number line or strip visuals. Emphasize position on number line.	Solve using visuals. Justify ordering based on numerators.
QTM Step	**Time**	**Teacher Activity**	**Student Activity**
Review	8 mins	Give worksheet: Compare 5 pairs of fractions (from textbook, e.g., 2/6 vs 5/6, 1/4 vs 3/4). Ask students to circle the larger one and explain.	Complete worksheet and discuss one answer with a partner or aloud.
Celebrate	5 mins	Award "Fraction Judge" cards. Chant: "Same bottom, bigger top – that's where comparison makes us stop!"	Share what they learned today. Join chant and celebrate with sticker or high five.

Lesson Plan 17: Ordering Fractions (Same Denominator)

Objectives (Reasoning Skills):

1. **Comparing:** Order fractions from smallest to greatest.
2. **Contrasting:** Analyze relative size using numerators.
3. **Generalizing:** Use comparison rules to order sets.
4. **Justifying:** Explain ordering decisions using diagrams.

QTM Step	Time	Teacher Activity	Student Activity

Enroll	5 mins	Show 3 pies divided into sixths. Shade 1/6, 3/6, 5/6. Ask: "Who gets the most? Who gets the least?"	Point and answer: "5/6 is the most." Begin thinking in order.
Experience	12 mins	Textbook example: Order 2/8, 5/8, 6/8. Use bars and cut-outs. Let students arrange them from smallest to largest.	Physically move paper strips to sort. Explain why order is correct.
Label	10 mins	Write: "When denominators are the same, the greater numerator shows a greater value." Show number line with 1/10 to 9/10.	Copy rule and try ordering: 3/10, 7/10, 2/10, 9/10 from book exercise.
Demonstrate	10 mins	Pick 4/6, 1/6, 2/6, 5/6. Ask 4 students to hold large fraction cards and come	Rearrange cards and explain their sequence. Use
QTM Step	**Time**	**Teacher Activity**	**Student Activity**
		up to arrange in order. Ask: "Why is this the right order?"	fingers or drawings to support answer.
Review	8 mins	Worksheet: Order 3 sets of fractions. One set includes real-world problem (e.g., 1/5 of pizza, 3/5 of pizza, 4/5 of pizza).	Complete worksheet, explain one example in front of class or in pair-share.
Celebrate	5 mins	Award "Order Master" ribbon. End with chant: "Top to bottom, rise and climb – ordering fractions takes no time!"	Join chant, smile, and take turns reading their favorite ordered set.

Lesson Plan 18: Adding Like Fractions

Objectives (Reasoning Skills):

1. Comparing: Students will compare parts added in like fractions.
2. Contrasting: Students will distinguish the impact of numerator changes.
3. Generalizing: Students will deduce the rule for adding like fractions.
4. Justifying: Students will explain why the denominator stays the same.

QTM Step	Time	Teacher Activity	Student Activity
Enroll	5 mins	Show 2 half pizzas. Ask: "If I have 1/2 + 1/2, how many pizzas do I have now?" Use real paper cutouts.	Predict and answer. Begin seeing fractional addition.
Experience	12 mins	Use textbook example: 1/4 + 2/4 = 3/4. Use fraction strips or paper circles.	Manipulate and label their own strips. Confirm by counting shaded sections.
Label	10 mins	Write rule: "Add numerators, keep the same denominator." Reinforce with 3/8 + 2/8 = 5/8.	Copy rule. Apply it to 2 examples from the textbook.
Demonstrate	10 mins	Work out 4/5 + 1/5. Ask student to explain why denominator didn't change.	Participate in board solution and peer review.
Review	8 mins	Worksheet: 5 problems with like denominators. Includes one real-life problem (e.g. measuring water).	Solve, compare answers, and explain one aloud.
Celebrate	5 mins	Award "Fraction Adder" badges. Lead chant: "Same bottom, tops we add — that makes math not so bad!"	Join chant and smile at achievement.

Lesson Plan 19: Subtracting Like Fractions

Objectives

1. Comparing: Compare original and remaining parts.
2. Contrasting: Differentiate between addition and subtraction results.
3. Generalizing: Deduce the rule for subtracting like fractions.
4. Justifying: Explain why only numerators are subtracted.

QTM Step	Time	Teacher Activity	Student Activity
Enroll	5 mins	Present story: "Sara ate 3/4 of a pizza and gave away 1/4. How much did she eat now?"	Answer: 3/4 - 1/4 = 2/4. Think and justify their answer.

Experience	12 mins	Use textbook example: 5/6 - 2/6 = 3/6. Use fraction bars.	Draw or arrange bars and subtract. Confirm the result visually.
Label	10 mins	Rule: "Subtract numerators. Keep denominator same." Model with 4/8 - 1/8.	Copy rule. Apply to 2 new examples from textbook.
Demonstrate	10 mins	Ask students to solve: 6/7 - 3/7. Ask them to explain why denominator stays unchanged.	Work in pairs and explain on board or paper.
Review	8 mins	Worksheet: 5 subtraction problems. Includes picture-based problems.	Complete and peer-check with teacher support.
Celebrate	5 mins	Award "Subtract Champ" badge. Chant: "Same bottom, top goes down — fraction fun all around!"	Reflect and share improvement.

Lesson Plan 20: Adding Unlike Fractions

Objectives

1. Comparing: Recognize difference in denominators.
2. Contrasting: Understand how unlike denominators affect sums.
3. Generalizing: Learn LCM to convert to like denominators.
4. Justifying: Explain each step of finding common denominators.

QTM Step	Time	Teacher Activity	Student Activity
Enroll	5 mins	Show 1/2 of chocolate and 1/3 of same size bar. Ask: "Can we just add 1/2 + 1/3?"	Predict and realize sizes are different.
Experience	12 mins	Use textbook example: 1/2 + 1/3. Find LCM of 2 and 3 is 6. Convert: 3/6 + 2/6 = 5/6.	Do similar with 1/4 + 1/6 using visual charts.
Label	10 mins	Rule: "Find LCM. Convert both fractions to like denominators. Add numerators."	Copy rule. Try with 2/5 + 1/3 from the book.

Demonstrate	10 mins	Solve on board: 3/4 + 2/3 = 9/12 + 8/12 = 17/12 = 1 5/12. Highlight steps.	Try example on board. Explain conversion steps to peers.
Review	8 mins	Worksheet: 4 problems. Use one real-life example like juice mixing.	Solve with conversion shown. Peer-check with partner.
Celebrate	5 mins	Award "Denominator Fixer" badge. Chant: "Make bottoms match, then go and catch — the top that sums!"	Join chant and reflect on effort.

A. **Lesson Plan 21: Subtracting Unlike**

Fractions Objectives (Reasoning Skills):

1. *Comparing:* Compare different-sized parts.
2. *Contrasting:* Distinguish unlike vs. like subtraction steps.
3. *Generalizing:* Apply LCM in subtraction.
4. *Justifying:* Explain all steps in the process.

QTM Step	Time	Teacher Activity	Student Activity
Enroll	5 mins	Present problem: "You ate 2/3 of pie but gave 1/4 to friend. How much did you eat now?"	Think and respond. Realize denominators don't match.
Experience	12 mins	Use textbook example: 3/4 - 1/6. LCM = 12. Convert: 9/12 - 2/12 = 7/12.	Try 5/6 - 1/4 using visual fraction wall.
Label	10 mins	Rule: "Find LCM. Convert both to same denominator. Subtract numerators."	Copy rule and solve: 2/5 - 1/3.
Demonstrate	10 mins	Solve on board: 7/8 - 1/6. Ask for reason why LCM is used.	Try and explain with partner. Share answers.
Review	8 mins	Worksheet: 4 problems. Use story problem with baking (e.g., flour used).	Complete, share, and check.

Celebrate	5 mins	Award “Subtraction Solver” badge. Chant: “Change the bottom, take the top — subtract like a math nonstop!”	Join chant and share one solved example.

Lesson Plan 22: Multiplying Fractions by Whole Numbers (Day 1)
Objectives (Reasoning Skills):

1. Comparing: Recognize multiplication as repeated addition.
2. Contrasting: Differentiate multiplication from simple addition.
3. Generalizing: Identify rule: Multiply numerator × whole number.
4. Justifying: Explain why denominator stays the same.

QTM Step	Time	Teacher Activity	Student Activity
Enroll	5 mins	Ask: “If I have 3 halves of cake, how many halves in total?” Link to 3 × 1/2.	Predict total and begin thinking of multiplication of fractions.
Experience	12 mins	Use textbook example: 3 × 1/4 = 3/4. Show using shaded fraction strips.	Use colored strips to represent repeated addition and confirm results visually.
Label	10 mins	Rule: Multiply numerator × whole number. Denominator remains the same. Show: 4 × 2/5 = 8/5 = 1 3/5.	Copy rule. Apply to example 5 × 1/3 from textbook.
Demonstrate	10 mins	Solve 2 × 3/4 and 6 × 1/6. Highlight steps. Ask students to explain why denominator remains unchanged.	Solve similar problems on board. Explain to peers.
Review	8 mins	Worksheet: 4 problems from textbook. Include one word problem (e.g. 4 bowls, each 3/5 filled).	Complete worksheet and explain one problem to class.
Celebrate	5 mins	Award “Fraction Multiplier” badge. Chant: “Times the top, bottom stays — multiplying the fraction way!”	Join chant and smile.

Lesson Plan 23: Multiplying Fractions by Fractions

Objectives (Reasoning Skills):

1. Comparing: Compare area model vs numerical method.
2. Contrasting: Understand why both numerator and denominator are multiplied.
3. Generalizing: Learn rule: numerator × numerator, denominator × denominator.
4. Justifying: Explain meaning using diagrams.

QTM Step	Time	Teacher Activity	Student Activity
Enroll	5 mins	Show a shaded square: "What is 1/2 of 1/3?" Use diagram.	Think and predict: "1/6." Discuss and estimate.
Experience	12 mins	Use area model to represent 1/2 × 1/3. Refer to textbook example with diagrams.	Draw grid and shade accordingly. Confirm answer as 1/6.
Label	10 mins	Rule: Multiply numerator × numerator, denominator × denominator. Show: 2/3 × 3/4 = 6/12 = 1/2.	Copy rule. Try two examples from textbook.
Demonstrate	10 mins	Solve 2/5 × 3/7. Highlight steps and confirm with area model.	Practice similar example with partner. Explain to class.
Review	8 mins	Worksheet: 3 multiplication problems with visuals. One real-life example (e.g. juice recipe).	Complete worksheet. Draw or explain one example.
Celebrate	5 mins	Award "Fraction Multiplier Pro" badge. Chant: "Top times top, bottom too — that's the fraction trick we do!"	Join chant and reflect.

Lesson Plan 24: Dividing Fractions by Whole Numbers

Objectives (Reasoning Skills):

1. Comparing: Understand sharing fraction into groups.
2. Contrasting: Recognize that the total part remains but gets split.

3. Generalizing: Learn rule: Multiply denominator × whole number.
4. Justifying: Use pictures to explain why result is smaller.

QTM Step	Time	Teacher Activity	Student Activity
Enroll	5 mins	Ask: "You have 1/2 of a cake. Can you share it with 2 friends?"	Think and suggest: "Each gets 1/4." Discuss why.
Experience	12 mins	Textbook example: 1/2 ÷ 2 = 1/4. Show visually with fraction strips.	Cut and divide drawings to show division.
Label	10 mins	Rule: To divide fraction by whole, multiply denominator by whole number.	Copy rule. Try with 3/5 ÷ 3.
Demonstrate	10 mins	Solve 2/3 ÷ 4 = 2/12 = 1/6. Use diagrams. Ask students: "Why did denominator increase?"	Work on similar question: 3/4 ÷ 2. Explain in own words.
Review	8 mins	Worksheet: 4 division problems. One cooking scenario (e.g. 1/3 cup divided among 3 muffins).	Solve and check with peer. Discuss results.
Celebrate	5 mins	Give "Divider Star" sticker. Chant: "Divide the part, make it thin — sharing always makes us win!"	Join chant. Reflect.

Lesson Plan 25: Dividing Fractions by Fractions

Objectives (Reasoning Skills):

1. Comparing: Compare two fractions in division form.
2. Contrasting: Identify relationship between invert and multiply.
3. Generalizing: Learn rule: multiply by reciprocal.
4. Justifying: Explain process using models and logic.

QTM Step	Time	Teacher Activity	Student Activity
Enroll	5 mins	Ask: "If half of a recipe takes 1/4 cup, how many 1/4s are in 1/2?"	Predict answer. Understand dividing into parts.

Experience	12 mins	Use textbook example: 1/2 ÷ 1/4 = 2. Show visual number line and groupings.	Count how many 1/4s in 1/2 using pictures.
Label	10 mins	Rule: Keep first fraction, flip second (reciprocal), then multiply.	Copy rule. Practice on 2/3 ÷ 1/6 = 2/3 × 6/1 = 12/3 = 4.
Demonstrate	10 mins	Solve 3/4 ÷ 1/2 = 3/4 × 2/1 = 6/4 = 1 1/2. Use visuals.	Try similar: 5/6 ÷ 1/3. Share answers with partner.
Review	8 mins	Worksheet: 4 problems. One real-world problem (e.g. how many 1/5 cups in 2/3 cup).	Solve and explain with partner. Review and reflect.
Celebrate	5 mins	Award "Reciprocal Hero" badge. Chant: "Flip the second, multiply — then the answer will multiply high!"	Chant and clap. Share fun example.

lesson plan 26: Applying Fractions in Real-World Problems

Objectives

1. Comparing: Compare quantities and parts in real-life settings.
2. Contrasting: Differentiate between types of operations required.
3. Generalizing: Use known fraction rules to solve everyday problems.
4. Justifying: Explain solution steps with reasoning and math vocabulary.

QTM Step	Time	Teacher Activity	Student Activity
Enroll	5 mins	Ask: "If you drank 3/4 of a bottle in the morning and 1/4 in the evening, did you finish it?"	Think and respond. Begin reflecting on real-life use of fractions.
Experience	12 mins	Use textbook problem: A recipe needs 2/3 cup flour. You have only 1/3 cup. Ask: "What fraction is missing?"	Solve by drawing or using fraction strips. Share and discuss answers.

Label	10 mins	Define: "Real-world problems require choosing the correct operation — add, subtract, multiply, or divide."	Write definition. Copy chart from textbook matching problems with operations.
Demonstrate	10 mins	Model a shopping example: 1/2 meter of ribbon needed for 3 gifts → 3 × 1/2 = 3/2 = 1 1/2 meters.	Solve and explain a pizza problem: "If 3 people share 3/4 equally, how much per person?"
Review	8 mins	Assign worksheet with 4 story problems from textbook (mix of all operations). Let students use diagrams or equations.	Solve, check in pairs, and explain one solution to the class.
Celebrate	5 mins	Award "Fraction Solver" badge. Chant: "In life and math, fractions rule — solving real problems makes us cool!"	Join chant. Reflect on where they used fractions outside school.

7.1 Appendix B lesson plans for control group

Lesson Plan 1: Divisibility Rule of 2

Objectives:

- Recognize even numbers.
- Apply the rule: A number is divisible by 2 if it ends in 0, 2, 4, 6, or 8.

Materials: Whiteboard, marker, flashcards, worksheet.

1. Introduction (5 mins):
Write 10, 25, 18, and 43 on the board. Ask, "Which of these can be divided by 2?"

2. Presentation (20 mins):

- Explain the rule: *"A number is divisible by 2 if the last digit is 0, 2, 4, 6, or 8."*
- Give examples: 32 , 47 , 100
- Use visuals (number line or chart) to reinforce understanding.
- Show counter-examples and explain why they don't qualify.

3. Guided Practice (10 mins):

- Solve: 58, 81, 90, 33, 76, 67 together. Ask: "What is the last digit?"
- Students answer orally, teacher writes result.

4. Independent Practice (10 mins):

- Worksheet: 20 numbers. Write "Yes" or "No" for each based on divisibility by 2.

5. Closure (5 mins):

- Recap rule: "If a number ends in 0, 2, 4, 6, or 8, it's divisible by 2."
- Homework: Check 94, 53, 72, 101 for divisibility.

- ## Lesson Plan 2: Divisibility Rule of 3

Objectives:

- Use digit sum to check divisibility by 3.
- Apply to two- and three-digit numbers.

Materials: Digit sum chart, board, worksheet.

1. Introduction (5 mins):
Write 12, 15, 22, 29. Ask: "Can we divide these by 3?"

2. Presentation (20 mins):

- Rule: *"If the sum of a number's digits is divisible by 3, the number is too."*
- Examples:
  - 123 → 1+2+3=6 →
  - 124 → 1+2+4=7 →
- Do 5 examples on the board (teacher-led only). Explain each step.

3. Guided Practice (10 mins):

- Solve: 213, 240, 315, 101, 188 on the board.
- Ask: "What's the digit sum? Is it divisible by 3?"

4. Independent Practice (10 mins):

- Worksheet: 10 numbers. Students find digit sum, write Yes/No.

5. Closure (5 mins):

- Recap rule and give homework: Check 145, 147, 225, 307.

- ## Lesson Plan 3: Divisibility Rule of 5

Objectives:

- Identify numbers ending in 0 or 5.
- Apply the rule to test divisibility by 5.

Materials: Board, number chart, worksheet.

1. Introduction (5 mins):
Ask: "Is 25 divisible by 5? What about 28?"

2. Presentation (20 mins):

- Rule: *"A number is divisible by 5 if it ends in 0 or 5."*
- Examples: 45, 30, 85 | 41, 73
- Write 6 examples with explanations.

3. Guided Practice (10 mins):

- Solve 90, 77, 55, 102, 40 together.

4. Independent Practice (10 mins):

- Worksheet: 12 numbers. Tick if divisible by 5.

5. Closure (5 mins):

- Summarize rule. Homework: 210, 219, 135, 141.

Lesson Plan 4: Divisibility Rule of 10

Objectives:

- Recognize numbers ending in 0.
- Apply rule to real-life examples (e.g., money).

Materials: Number cards, chart, worksheet.

1. Introduction (5 mins):
Ask: "Is 80 divisible by 10? What about 83?"

2. Presentation (20 mins):

- Rule: *"A number ending in 0 is divisible by 10."*
- Show examples: 20, 30, 90 | 33, 57
- Highlight last digit and explain why.

3. Guided Practice (10 mins):

- Solve 100, 63, 40, 71, 120 on the board.

4. Independent Practice (10 mins):

- Worksheet: Circle numbers divisible by 10 from list of 15.

5. Closure (5 mins):

- Summary and homework: 250, 264, 470, 311.

Lesson Plan 5: Introduction to Factors

Objectives:

- Understand what a factor is.
- Identify factor pairs.

Materials: Whiteboard, marker, worksheet.

1. Introduction (5 mins):
Ask: "How many equal groups can we make with 12 candies?"

2. Presentation (20 mins):

- Definition: *"A factor divides a number exactly."*
- Factors of 12 → 1×12, 2×6, 3×4
- List factor pairs for: 8, 10, 16

3. Guided Practice (10 mins):

- Work through factors of 15 and 18 with students.

4. Independent Practice (10 mins):

- Worksheet: Write factor pairs for 3 numbers. Circle largest factor.

5. Closure (5 mins):

- Recap: "Factors divide without a remainder." Homework: Factors of 20 and 24.

- ## Lesson Plan 6: Exploring Factor Patterns

Objectives:

- Compare numbers based on their number of factors.
- Understand difference between numbers with only two factors (primes) and more (composites).

Materials: Board, number chart, factor worksheet.

1. Introduction (5 mins):
Ask: "Why does 13 only divide by 1 and itself, but 12 has many factors?"

2. Presentation (20 mins):

- Use a T-chart to list factors of 11–20.
- Highlight numbers with only two factors (e.g., 11, 13, 17) vs. those with many (e.g., 12, 15, 18).
- Explain how factor count helps identify primes vs. composites.

3. Guided Practice (10 mins):
- Work through factor lists for 14 and 16 on board with class.

4. Independent Practice (10 mins):

- Students receive numbers 21–30 and list all factor pairs.

5. Closure (5 mins):

- Ask: "Which number had the most factors?" Homework: Find two numbers between 31–40 that are prime.

- ## Lesson Plan 7: Understanding Multiples

Objectives:

- Define multiples.
- Use skip counting to generate multiples of numbers.

Materials: Number line/chart, worksheet, colored markers.

1. Introduction (5 mins):
Ask: "What are the first five multiples of 3?" Write on board: 3, 6, 9, 12, 15.

2. Presentation (20 mins):

- Definition: *"A multiple is the result of multiplying a number by 1, 2, 3, etc."*
- Show $4 \times 1 = 4$, $4 \times 2 = 8$, etc.
- Do the same for 5 and 6. Use a chart to show patterns.

3. Guided Practice (10 mins):

- Together, list multiples of 3 and 5 up to 30.

4. Independent Practice (10 mins):

- Worksheet: List first 6 multiples of 4, 6, and 9.

5. Closure (5 mins):

- Recap rule. Homework: List the first five multiples of 11 and 12.

- ## Lesson Plan 8: Common Multiples and LCM

Objectives:

- Identify common multiples.
- Find the Least Common Multiple (LCM).

Materials: Board, Venn diagram template, worksheet.

1. Introduction (5 mins):
Ask: "If I count by 3s and you by 4s, when will we both say the same number?"

2. Presentation (20 mins):

- Write multiples of 3 and 4 on board:
  3, 6, 9, 12, 15...
  4, 8, 12, 16...
- Circle common numbers and explain LCM = smallest common multiple.
- Repeat for 5 and 6.

3. Guided Practice (10 mins):

- Find LCM of 2 & 3, 4 & 6 together using listing method.

4. Independent Practice (10 mins):

- Worksheet: Use Venn diagram to find LCM of 3 given pairs.

5. Closure (5 mins):

- Recap: "LCM helps us sync patterns." Homework: LCM of 6 & 8, and 4 & 10.

- ## Lesson Plan 9: Prime Numbers

Objectives:

- Define a prime number.
- Identify prime numbers up to 50 using factor count.

Materials: Prime number chart (1–50), board, worksheet.

1. Introduction (5 mins):
Ask: "Can 7 be divided by anything other than 1 and 7?" (No → prime)

2. Presentation (20 mins):

- Define: *"A prime number has exactly two factors: 1 and itself."*
- List and explain:
  - Prime: 2, 3, 5, 7, 11
  - Not prime: 4, 6, 8
- Explain how even numbers >2 are not prime.

3. Guided Practice (10 mins):

- Go through numbers 1–20. Students tell whether they're prime or not.

4. Independent Practice (10 mins):

- Worksheet: Circle prime numbers from a list of 30.

5. Closure (5 mins):

- Recap: "Only two factors = prime." Homework: Check if 17, 18, 23, 27 are prime.

- ## Lesson Plan 10: Composite Numbers

Objectives:

- Define composite numbers.
- Differentiate between prime and composite using number of factors.

Materials: Whiteboard, marker, factor chart, worksheet.

1. Introduction (5 mins):
Ask: "Why can we group 12 in so many ways (1×12, 2×6, 3×4)?"

2. Presentation (20 mins):

- Define: *"A composite number has more than two factors."*
- Examples: 4, 6, 8, 10 (→ factors more than 2)
- Contrast with primes: 5, 7, 11

3. Guided Practice (10 mins):

- Solve: List factors for 9, 10, 12 and determine if composite.

4. Independent Practice (10 mins):

- Worksheet: Identify composite numbers from 1–30 and underline their factors.

5. Closure (5 mins):

- Recap: “Composite = more than two factors.” Homework: List all composite numbers from 31–40.

- ## Lesson Plan 11: Introduction to Composite Numbers

Objectives:

- Define composite numbers.
- Identify composite numbers up to 20.
- Compare composite and prime numbers.

Materials: Whiteboard, factor chart, number line, worksheet.

1. Introduction (5 mins):
Ask: “Can you divide 12 evenly in more than one way?” Write: 1×12, 2×6, 3×4.

2. Presentation (20 mins):

- Define: *“A composite number has more than two factors.”*
- Examples:
    - 4 → 1, 2, 4
    - 6 → 1, 2, 3, 6
    - 9 → 1, 3, 9
- Show contrast with 7 and 11 (primes).

3. Guided Practice (10 mins):

- Find all factors of 10, 14, 16 together.
- Decide if composite.

4. Independent Practice (10 mins):

- Worksheet: Identify and label 10 composite numbers up to 30.

5. Closure (5 mins):

- Recap: “Composite numbers have more than two factors.”
- Homework: List all composite numbers between 21–40.

- ## Lesson Plan 12: Exploring Composite Numbers

Objectives:

- Identify patterns in composite numbers.
- Use factor trees to justify composite classification.

Materials: Chart paper, colored markers, worksheet.

1. Introduction (5 mins):

Show number cards: 15 and 17. Ask: “Which one can be grouped more than one way?”

2. Presentation (20 mins):

- Explain how to make factor trees.
- Example:
  - 18 → 2×9 → 3×3 → Factors: 1, 2, 3, 6, 9, 18
- Explain shortcut: If even and >2, likely composite.

3. Guided Practice (10 mins):

- Make factor trees for 12 and 24 together.

4. Independent Practice (10 mins):

- Worksheet: Factor trees for 21–30. Circle largest factor.

5. Closure (5 mins):

- Recap: “Composite numbers have multiple groupings.”
- Homework: Make factor trees for 27 and 30.

- ## Lesson Plan 13: Understanding Improper Fractions

Objectives:

- Recognize and define improper fractions.
- Compare improper fractions to whole numbers.

Materials: Paper strips, board diagrams, worksheet.

1. Introduction (5 mins):
Show 7 half-sheet strips. Ask: “How many full papers is that?” (3 full, 1 half → 7/2)

2. Presentation (20 mins):

- Define: *“Improper fractions have numerators greater than denominators.”*
- Examples: 7/2, 9/4, 11/5
- Use visuals to show they’re greater than 1 whole.

3. Guided Practice (10 mins):

- Represent 5/2 and 8/3 on the board using drawings.

4. Independent Practice (10 mins):

- Worksheet: Identify whether each of 10 fractions is proper or improper.

5. Closure (5 mins):

- Recap: “Numerator > denominator = improper fraction.”
- Homework: Write 3 improper fractions greater than 1.

- ## Lesson Plan 14: Converting Improper Fractions to Mixed Numbers
  Objectives:

- Convert improper fractions to mixed numbers using division.
- Explain conversion process.

Materials: Pizza slice cut-outs, number line, worksheet.

1. Introduction (5 mins):
Ask: “If 11 slices make a pizza, how many full pizzas can you make from 11 slices if each pizza needs 4 slices?”

2. Presentation (20 mins):

- Explain: *“Divide numerator ÷ denominator. Quotient = whole, remainder = numerator.”*
- Example: 11/4 → 2 R3 → 2 3/4
- Show board example with 13/5.

3. Guided Practice (10 mins):

- Solve: 9/2 and 10/3 on board.

4. Independent Practice (10 mins):

- Worksheet: Convert 5 improper fractions to mixed numbers.

5. Closure (5 mins):

- Recap: “Top ÷ bottom gives the whole. Remainder stays numerator.”
- Homework: Convert 15/4, 17/5, 22/6.

- ## Lesson Plan 15: Converting Mixed Numbers to Improper Fractions
  Objectives:

- Convert mixed numbers to improper fractions.
- Use and explain the conversion rule.

Materials: Visual fraction bars, board examples, worksheet.

1. Introduction (5 mins):
Ask: “If you ate 3 pizzas and 1/4 of another, how many fourths is that?” (Answer: 13/4)

2. Presentation (20 mins):

- Rule: *"Multiply whole × denominator, then add numerator. Keep denominator same."*
- Example: 2 3/5 → (2×5)+3 = 13/5
- Show steps clearly with visuals.

3. Guided Practice (10 mins):

- Convert 1 2/3 and 3 1/2 together on board.

4. Independent Practice (10 mins):

- Worksheet: Convert 5 mixed numbers to improper fractions.

5. Closure (5 mins):

- Recap rule. Homework: Convert 4 2/5, 2 1/4, and 5 1/6.

- ## Lesson Plan 16: Comparing Fractions with Same Denominator

Objectives:

- Compare like fractions.
- Use numerators to determine which fraction is greater.

Materials: Fraction bars or paper strips, whiteboard, number line, worksheet.

1. Introduction (5 mins):
Show 3/5 and 4/5 on board. Ask: "Which one shows more?"

2. Presentation (20 mins):

- Rule: *"When denominators are the same, compare numerators. Larger numerator = greater fraction."*
- Examples:
  - 5/8 vs 2/8 → 5/8 is greater
  - 1/4 vs 3/4 → 3/4 is greater
- Show using drawings or bar visuals.

3. Guided Practice (10 mins):

- Compare: 2/6 vs 5/6, 3/10 vs 7/10, 6/9 vs 8/9.

4. Independent Practice (10 mins):

- Worksheet: Circle the greater fraction from 10 pairs.

5. Closure (5 mins):

- Recap: "Same bottom, bigger top means greater value."

- Homework: Compare 4/7 vs 6/7, 5/10 vs 8/10, 3/12 vs 11/12.

- ## Lesson Plan 17: Ordering Fractions with Same Denominator

Objectives:

- Order like fractions from least to greatest.
- Explain comparison using numerators.

Materials: Board, paper strips, number line, worksheet.

1. Introduction (5 mins):
Write: 2/6, 4/6, 5/6. Ask: "Can we order them from smallest to biggest?"

2. Presentation (20 mins):

- Rule: *"If denominators are the same, order by numerators."*
- Example: 3/10, 7/10, 9/10 → 3/10 < 7/10 < 9/10
- Show visual model to support idea.

3. Guided Practice (10 mins):

- Order: 1/7, 4/7, 6/7; 2/9, 5/9, 8/9

4. Independent Practice (10 mins):

- Worksheet: Order 3–4 sets of fractions.

5. Closure (5 mins):

- Recap: "Look at numerators when bottoms are the same."
- Homework: Order: 2/8, 7/8, 5/8; 1/6, 6/6, 4/6

- ## Lesson Plan 18: Adding Like Fractions

Objectives:

- Add fractions with same denominator.
- Explain why denominator remains unchanged.

Materials: Fraction strips, board, worksheet.

1. Introduction (5 mins):
Ask: "If I eat 1/4 of a pizza and then 2/4 more, how much in total?"

2. Presentation (20 mins):

- Rule: *"Add numerators. Keep denominator the same."*
- Examples:

- 2/5 + 1/5 = 3/5
- 3/8 + 2/8 = 5/8

- Visuals: show shaded fraction parts.

3. Guided Practice (10 mins):

- Solve: 4/6 + 1/6, 2/7 + 3/7

4. Independent Practice (10 mins):

- Worksheet: 6 addition problems (like denominators).

5. Closure (5 mins):

- Recap: "Add tops, keep the bottom the same."
- Homework: Solve: 5/9 + 2/9, 3/10 + 6/10, 1/3 + 2/3.

- ## Lesson Plan 19: Subtracting Like Fractions

Objectives:

- Subtract fractions with same denominator.
- Justify why only numerators are subtracted.

Materials: Fraction bars, board, subtraction worksheet.

1. Introduction (5 mins):
Ask: "Sara ate 3/4 of a pizza and gave 1/4 away. How much did she eat now?"

2. Presentation (20 mins):

- Rule: *"Subtract numerators. Keep denominator same."*
- Examples:
  - 5/6 - 2/6 = 3/6
  - 4/8 - 1/8 = 3/8
- Show using colored fraction bars or pizza cutouts.

3. Guided Practice (10 mins):

- Solve: 6/7 - 3/7, 7/10 - 5/10

4. Independent Practice (10 mins):

- Worksheet: 5 problems, visuals provided.

5. Closure (5 mins):

- Recap: "Same bottom, subtract tops."
- Homework: 8/9 - 2/9, 5/6 - 4/6, 3/5 - 1/5

- ## Lesson Plan 20: Adding Unlike Fractions

Objectives:

- Add fractions with different denominators.
- Use LCM to make denominators same.

Materials: Fraction wall, board, worksheet.

1. Introduction (5 mins):
Show 1/2 and 1/3 of same-sized bars. Ask: "Can we add these directly?"

2. Presentation (20 mins):

- Rule: *"Find LCM, make denominators same, then add."*
- Example:
  - 1/2 + 1/3 → LCM = 6 → 3/6 + 2/6 = 5/6
- Show process on board step by step.

3. Guided Practice (10 mins):

- Solve: 1/4 + 1/6, 2/5 + 1/3

4. Independent Practice (10 mins):

- Worksheet: 4 problems with space to show working.

5. Closure (5 mins):

- Recap: "Change to like denominators, then add."
- Homework: 3/4 + 2/3, 1/5 + 1/6

- ## Lesson Plan 21: Subtracting Unlike Fractions

Objectives:

- Subtract fractions with different denominators.
- Convert to like denominators using LCM.

Materials: Fraction wall, board, subtraction worksheet.

1. Introduction (5 mins):
Pose a problem: "You ate 2/3 of a pie and gave away 1/4. How much is left?"

2. Presentation (20 mins):

- Rule: *"To subtract unlike fractions, find the LCM of denominators, convert both, subtract numerators."*

- Example:
  - 2/3 - 1/4 → LCM = 12 → 8/12 - 3/12 = 5/12
- Show step-by-step with diagram or number line.

3. Guided Practice (10 mins):

- Solve: 3/4 - 1/6 and 5/6 - 1/3 on the board.

4. Independent Practice (10 mins):

- Worksheet: 4 subtraction problems with space to show conversion steps.

5. Closure (5 mins):

- Recap: "Find LCM, convert, subtract."
- Homework: 2/5 - 1/3, 3/4 - 1/6, 4/5 - 2/10

- ## Lesson Plan 22: Multiplying Fractions by Whole Numbers

Objectives:

- Multiply a fraction by a whole number.
- Explain multiplication as repeated addition.

Materials: Fraction strips, visual chart, board, worksheet.

1. Introduction (5 mins):
Ask: "If you have 3 halves of cake, how many halves do you have in total?"

2. Presentation (20 mins):

- Rule: *"Multiply numerator by whole number. Keep denominator the same."*
- Example:
  - 3 × 1/4 = 3/4
  - 4 × 2/5 = 8/5
- Explain with repeated addition (e.g. 1/4 + 1/4 + 1/4 = 3/4)

3. Guided Practice (10 mins):

- Solve: 2 × 3/5 and 5 × 1/3 with teacher.

4. Independent Practice (10 mins):

- Worksheet: 5 problems multiplying fractions by whole numbers.

5. Closure (5 mins):

- Recap: "Multiply top by whole number."
- Homework: 6 × 1/2, 3 × 2/3, 4 × 3/8

- ## Lesson Plan 23: Multiplying Fractions by Fractions

Objectives:

- Multiply two fractions.
- Use the rule: multiply numerators, multiply denominators.

Materials: Grid paper, board, area model visuals, worksheet.

1. Introduction (5 mins):
Ask: "What is 1/2 of 1/3?" Predict the result.

2. Presentation (20 mins):

- Rule: *"Multiply numerator × numerator, and denominator × denominator."*
- Example:
    - 1/2 × 1/3 = 1/6
    - 2/3 × 3/4 = 6/12 = 1/2
- Show visual model with shaded boxes.

3. Guided Practice (10 mins):

- Solve 2/5 × 3/7 and 3/4 × 1/2 together.

4. Independent Practice (10 mins):

- Worksheet: 4 fraction × fraction problems with visuals.

5. Closure (5 mins):

- Recap: "Multiply tops, multiply bottoms."
- Homework: 4/5 × 2/3, 1/6 × 3/8

- ## Lesson Plan 24: Dividing Fractions by Whole Numbers

Objectives:

- Divide a fraction by a whole number.
- Understand that the result is smaller.

Materials: Paper strips, board, worksheet.

1. Introduction (5 mins):
Ask: "If you have 1/2 of a cake and share it with 2 friends, how much does each get?"

2. Presentation (20 mins):

- Rule: *"To divide a fraction by a whole number, multiply the denominator by the* *whole number."*

- Example:
  - 1/2 ÷ 2 = 1/4
  - 3/5 ÷ 3 = 3/15 = 1/5
- Use visuals and diagrams to demonstrate.

3. Guided Practice (10 mins):

- Solve: 2/3 ÷ 4, 3/4 ÷ 2

4. Independent Practice (10 mins):

- Worksheet: 4 problems with diagrams.

5. Closure (5 mins):

- Recap: "Dividing by a whole number increases the denominator."
- Homework: 3/5 ÷ 2, 5/6 ÷ 3

- ## Lesson Plan 25: Dividing Fractions by Fractions

Objectives:

- Divide one fraction by another.
- Use the "keep, change, flip" rule (multiply by reciprocal).

Materials: Board, visual aids, worksheet.

1. Introduction (5 mins):
Ask: "If a recipe uses 1/4 cup per serving, how many 1/4s are in 1/2?"

2. Presentation (20 mins):

- Rule: *"Keep the first fraction, change division to multiplication, flip the second fraction."*
- Example:
  - 1/2 ÷ 1/4 = 1/2 × 4/1 = 4/2 = 2
  - 2/3 ÷ 1/6 = 2/3 × 6/1 = 12/3 = 4
- Use diagram to show grouping.

3. Guided Practice (10 mins):

- Solve: 3/4 ÷ 1/2, 5/6 ÷ 1/3

4. Independent Practice (10 mins):

- Worksheet: 4 division problems with space to show steps.

5. Closure (5 mins):

- Recap: “Keep, change, flip — then multiply.”
- Homework: 4/5 ÷ 2/3, 7/8 ÷ 1/4

- ## Lesson Plan 26: Applying Fractions in Real-World Problems

Objectives:

- Solve real-world word problems involving fractions.
- Choose the correct operation (add, subtract, multiply, divide).

Materials: Word problem worksheet, board, chart with fraction operation cues.

1. Introduction (5 mins):
Ask: “If you used 2/3 cup of flour but needed 1 whole cup, how much more do you need?”

2. Presentation (20 mins):

- Review when to use each operation:
  - Add (combine)
  - Subtract (difference)
  - Multiply (repeated/portion)
  - Divide (split/share)
- Show 2 examples from daily life:
  - Pizza sharing (division)
  - Recipe scaling (multiplication)

3. Guided Practice (10 mins):

- Solve:
  - “Ali drank 3/4 bottle in morning, 1/4 in evening. Did he finish?”
  - “One ribbon is 1/2 meter. How much for 3 ribbons?”

4. Independent Practice (10 mins):

- Worksheet: 4 story problems involving all operations.

5. Closure (5 mins):

- Recap: “Understand the story to decide the right operation.”
- Homework: Write your own fraction word problem and solve it.

7.2 Appendices -C Mathematical Reasoning Test

Table of Specification (TOS) for the Mathematical Reasoning Test (MRT)

Units	Comparing	Contrasting	Generalizing	Justifying	Total Items
Unit 4: Factors and Multiples	2	2	2	2	8
Unit 5: Fractions	3	3	3	3	12
Total	**5**	**5**	**5**	**5**	**20**

Rubric for the Mathematical Reasoning Test (MRT)

Criteria	Score Range	Performance Level	Description
Excellent	17–20	Mastery	Demonstrates comprehensive understanding of mathematical reasoning skills.
Proficient	13–16	Above Average	Applies reasoning skills effectively with minor errors.
Basic	9–12	Satisfactory	Shows partial understanding; needs improvement in some areas.
Below Basic	5–8	Developing	Limited understanding of reasoning skills; requires guided practice.
Needs Improvement	0–4	Beginning	Significant misconceptions; needs targeted intervention and support.

Mathematical Reasoning Skills Test

Name ——————————— **Date** ————————————

Total Questions: 20

Time 40 min

Instructions: Choose the one correct option for each question.

Comparing

Q1. Which number is a factor of both 18 and 24?

A. 5

B. 3

C. 10

D. 9

Q2. Which of the following is a common multiple of 3 and 4?

A. 7

B. 9

C. 12

D. 16

Q3. Which fraction is greater?

A. 1/3

B. 1/2

C. 1/4

D. 1/5

Q4. Which pair of fractions are equal?

A. 1/2 and 2/3

B. 2/4 and 1/2

C. 3/5 and 4/6

D. 3/6 and 1/3

Q5. Compare: 3/6 ___ 4/6

A. >

B. <

C. =

D. ≠

Contrasting

Q6. Which pair shows one factor and one multiple of 6?

A. 2 and 18

B. 6 and 12

C. 1 and 3

D. 3 and 9

Q7. Which of the following is a multiple but NOT a factor of 5?

A. 1

B. 5

C. 10

D. 25

Q8. Which of the following shows one proper and one improper fraction?

A. 2/3 and 4/5

B. 1/2 and 7/4

C. 5/8 and 6/7

D. 3/5 and 1/3

Q9. How is 3/4 different from 5/5?

A. 3/4 is less than 1, 5/5 equals 1

B. Both are improper

C. 3/4 is equal to 1

D. 5/5 is less than 1

Q10. Which pair shows unlike denominators?

A. 1/4 and 1/4

B. 3/5 and 2/5

C. 1/2 and 2/3

D. 4/4 and 4/4

B. **Generalizing**

Q11. All even numbers are multiples of which number?

A. 5

B. 3

C. 2

D. 10

Q12. If a number is divisible by both 2 and 3, it is also divisible by:

A. 4

B. 5

C. 6

D. 8

Q13. What is true about all unit fractions?

A. Denominator is always 1

B. Numerator is 1

C. They are greater than 1

D. They are improper

Q14. Fractions with the same denominator are called:

A. Unlike fractions

B. Unit fractions

C. Like fractions

D. Improper fractions

Q15. If numerator = denominator, the value is always:

A. 0

B. Less than 1

C. 1

D. More than 1

C. **Justifying**

Q16. Why is 7 a prime number?

A. It is even

B. It has only two factors: 1 and 7

C. It is divisible by 3

D. It ends in 7

Q17. Why is 12 not a prime number?

A. It's even

B. It ends in 2

C. It has more than two factors

D. It is less than 20

Q18. Why is 2/4 equal to 1/2?

A. They are different numbers

B. 2 is half of 4

C. 1/2 is bigger

D. 2 + 2 = 4

Q19. Why is 3/6 less than 5/6?

A. Because 3 is less than 5

B. Because 6 is more than 3

C. Because it is improper

D. because It is proper

Q20. Why can 6/9 be simplified?

A. Both numbers are odd

B. They have a common factor

C. Numerator is smaller

D. Denominator is 9

Answer key

Q1	B
Q2	C
Q3	B
Q4	B
Q5	B
Q6	A
Q7	C
Q8	B
Q9	A
Q10	C
Q11	C
Q12	C
Q13	B
Q14	C
Q15	C
Q16	B
Q17	C
Q18	B
Q19	A
Q20	B

Certificate of Validation

The Effect of Quantum Teaching Method on Mathematical Reasoning Skills at Elementary School Students

By Muqaddas Subhan

MS Scholar, Department of Teacher Education, Faculty of Education, International Islamic University Islamabad (IIUI), Pakistan

This is to certify that the researcher-developed instrument has been assessed by me, and I found that it is appropriate, reliable and valid for the process of data collection for the research title "The Effect of Quantum Teaching Method on Mathematical Reasoning Skills at Elementary School Students."

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Designation: Teacher

Institute: IMCB

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Date: 14:03:2025

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Date: 19|3|2025