

Quantum Learning or Hands-on Learning: Which is More Effective in Science Education?

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Abstract

The objective of this study is to examine the effects of Quantum Learning and Applied Learning activities on academic achievement, attitudes, motivation, and learning retention in science education. The present study employed a pre-test-post-test control group quasi-experimental design, with a total of 97 fourth-grade students participating in two experimental groups and one control group. During the eight-week process, Quantum Learning activities were implemented in Experimental Group 1, Applied Learning activities in Experimental Group 2, and the current curriculum was continued in the control group. The data were collected using achievement tests, attitude, and motivation scales. Two-factor ANOVA and MANOVA were used in the analysis. The findings indicated that Applied Learning exhibited superior efficacy in comparison to Quantum Learning with respect to academic achievement, attitude, motivation, and enduring learning.



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Introduction

Science is considered to be one of the most significant subjects in today's world, as it has been throughout history. It can be argued that science plays a pivotal role in the development of science and technology from the past to the present. Consequently, the attainment of success in the realm of science can be regarded as a crucial factor in achieving success in life. Science is a phenomenon that pervades every aspect of life. It has been demonstrated that early exposure to scientific concepts is conducive to the development of fundamental skills that are essential for future academic and professional success (Muñoz-Losa & Corbacho-Cuello, 2025). It is an established fact that science education facilitates the understanding of events encountered in daily life. This underscores the pivotal and indispensable role of science education for both students and society at a whole. In this context, it is imperative to emphasise the importance of imparting scientific knowledge to

individuals from a very early age. Indeed, empirical evidence shows that effective science education at primary school level improves children's ability to participate as active agents who can question, investigate and understand the scientific phenomena that surround them (DeLisi et al., 2021). Moreover, early science education has been demonstrated to inspire students to pursue careers in science, technology, engineering, and mathematics (STEM fields) (DeLisi et al., 2021). Individuals who acquire fundamental scientific knowledge are more likely to thrive in higher education and in subsequent aspects of their lives. Consequently, the utilisation of effective teaching methodologies and techniques in the instruction of scientific subjects is paramount. Within the paradigm of effective learning, interactions between students and teachers have the capacity to influence task performance and shape students' perceptions of their capabilities. The provision of adequate support to students has been demonstrated to enhance these perceptions (Xu et al., 2025). The judicious selection of efficacious teaching methods and techniques has been demonstrated to facilitate enhanced student comprehension and engagement with the subject matter.

As younger students, they require direct experiences with objects and phenomena. The combination of these tangible experiences with the related vocabulary is essential for the development of meaning and significance. This idea of thinking back and forth between observing physical phenomena and developing scientific ideas is fundamental for the development of scientific reasoning. In this regard, it is imperative to incorporate effective learning practices in science lessons for primary school students. A review of the extant literature reveals a plethora of studies that focus on science learning and the effectiveness of that learning (Acat & Ay, 2014; Erdem-Özcan & Uyanık, 2022; Karamustafaoğlu & Karamustafaoğlu, 2018). A commonality among these studies is the identification of effective teaching methodologies for science subjects across various grade and age groups. The present study aims to compare two distinct teaching practices, Quantum Learning and Hands-on Learning, with respect to their impact on students in primary school. The study will analyse the effects of these teaching practices on student learning outcomes.

Theoretical Framework

The present study examined the effectiveness of Quantum Learning and Hands-on Learning, two student-centred teaching practices based on the constructivist approach theory. Constructivist learning theory is predicated on the work of Piaget and Vygotsky. Constructivist theory posits that learning is a productive process and that knowledge is

constructed rather than discovered. This standpoint is rooted in constructivist theory, which posits that students acquire new knowledge by constructing their own understanding in a dynamic interplay with their existing perspectives. Indeed, the efficacy of the constructivist approach is evidenced by its ability to transform students' ideas from inaccurate to scientific. Adopting a student-centred approach, responsibility for the management and structuring of learning is afforded to the students themselves (Kavaz & Kocak, 2024; Uyanık, 2017). The constructivist learning theory extends the constructivist perspective by placing greater emphasis on the learning process, encouraging learning and focusing on the importance of learning by doing.

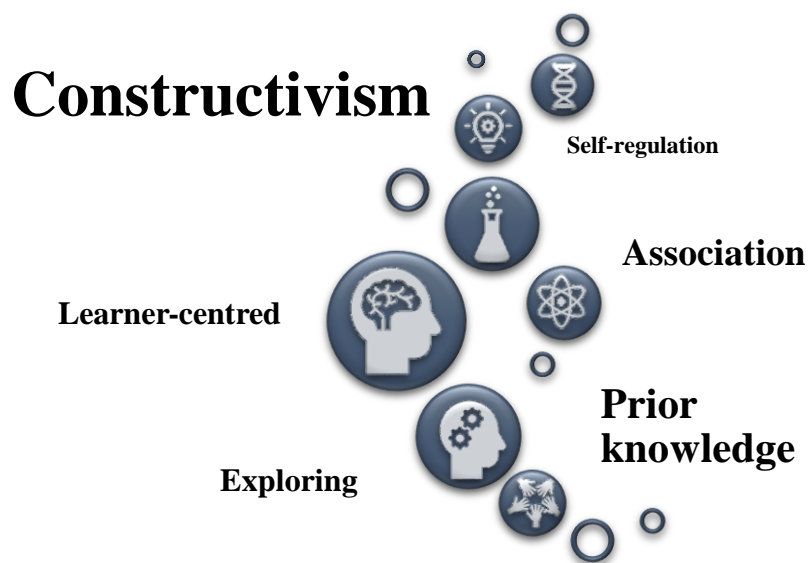


Figure 1. Constructivism

Constructivist theory proffers salient principles for the design of learning environments and experiences. The most effective learning occurs when individuals are engaged in the design process themselves. The products that students produce are reflective of the meaning-making processes that occur in their minds. These products function as either concrete objects that support thinking or as tools that embody cognitive processes. Furthermore, it is imperative to position learners as designers who participate in the negotiation of goals, roles, procedures, tools and instruments in design teams. In a learner-centred approach, it is imperative to acknowledge the diversity of learning characteristics among all learners, with a particular focus on those who demonstrate below-average performance. According to Harkema and Schout (2008), a learner-centred approach is predicated on the recognition that individual learners possess unique experiences, perspectives, backgrounds, talents, interests, capacities, and needs. She defines learner-

centred, from a research-based perspective, as a foundation for clarifying what is needed to create positive learning contexts to increase the likelihood that more students will experience success. To create an effective learning situation these conditions need to be met (Harkema & Schout, 2008):

- The learning environment should facilitate the exploration of meaning, ensuring that learners feel safe and accepted.
- Learners must be given frequent opportunities to confront new information and experiences in their search for meaning and understanding.
- New meaning and understanding should be acquired through a process of personal discovery.

In the domain of learning sciences, a fundamental principle posits that learning is a complex and disorganised process. The establishment of a connection between this intricate and disorganised body of knowledge and the construction of meaning constitutes a fundamental cognitive process. This study is predicated on the principles of constructivism. It is hypothesised that both Quantum Learning and Hands-on Learning activities will facilitate a construction process in students during the learning process, thereby enabling them to enter a cognitive structuring process. In the context of these learning practices, students blend and reconstruct both prior knowledge and newly acquired knowledge, thus emphasising the dynamic interaction between stored knowledge and new knowledge in the learning process. This process thus reveals the construction of knowledge.

Quantum Learning Model

Contemporary pedagogical practices have shifted towards student-centred teaching models, which prioritise student-centred learning activities. One notable example of a student-centred teaching model is the Quantum Learning Model (QLM). The QLM was developed in the 1980s, drawing from the educational philosophies of the renowned psychiatrist and educator Georgi Lazanov. The quantum learning model involves the utilisation of all neural networks in the brain, along with the preservation of structures and the incorporation of personal methods, with the objective of generating meaningful information (Vella, 2002). As with all pedagogical practices, Quantum Learning is predicated on a set of principles; as illustrated in Figure 2, these are delineated as follows.

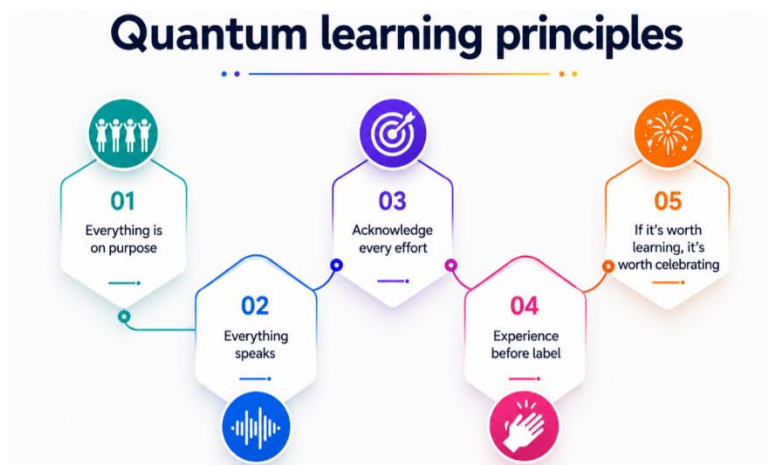


Figure 2. Quantum learning principles

The Quantum Learning, which aims to provide students with academic and life skills by integrating them on a common denominator, involves students actively in the learning process and develops their sense of responsibility. This model aims to help students make definitive judgments from their minds, and, in this respect, it can be said that it is shaped more within the framework of possibilities. The quantum learning model is based on the principle of learning to learn. It has been demonstrated to enhance students' motivation and facilitate the internalisation of abstract concepts. Quantum learning encourages students to engage in research, critical thinking, problem solving and teamwork, and it fosters an environment conducive to active learning. The Quantum Learning Model (QLM) is comprised of the following six interconnected stages, which are based on quantum learning principles, incorporate quantum learning techniques, are characterised by a part-whole relationship, and ultimately aim for success (DePorter, et al., 1999).

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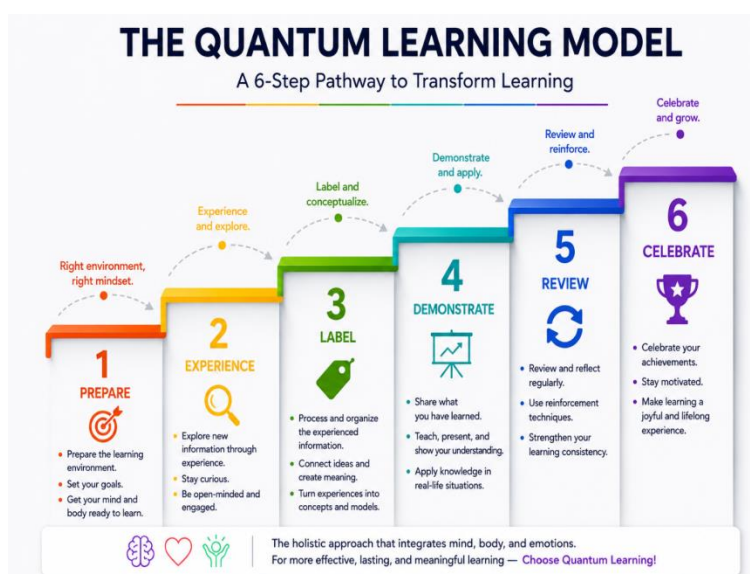


Figure 3. The QLM stages

As demonstrated in Figure 3, the Quantum Learning Model (QLM) comprises six distinct stages: capture stage, association stage, labelling stage, demonstration stage, repetition stage, and celebration stage.

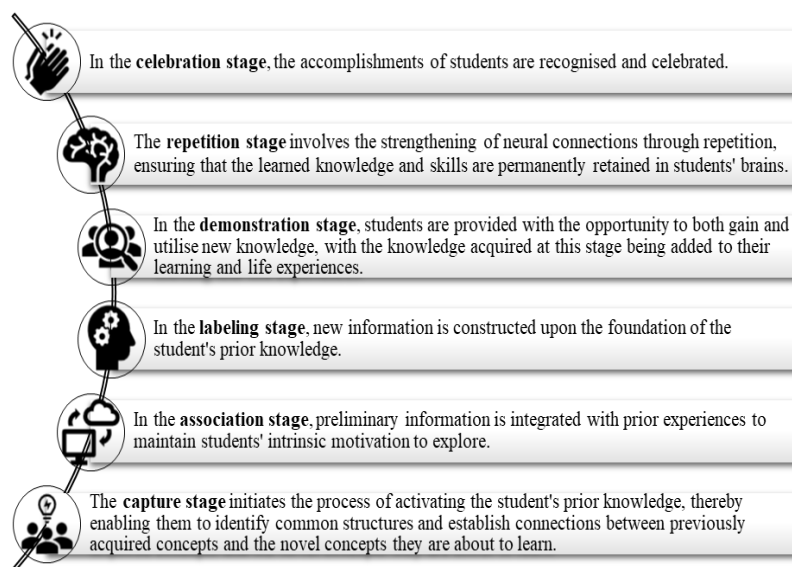


Figure 4. Quantum learning stages and processes

The theory of quantum learning is based on a number of principles. These principles, some of which form the basis for the creation of the quantum learning system, are as follows (DePorter, et al., 1999):

- ⇒ The learning environment is composed of several elements, including adequate lighting, appropriate colour schemes, positive posters, plants, props and music.
- ⇒ The purpose of the course is reflected in every aspect of its operation, which is conducted in accordance with the rhythm of a symphony orchestra.
- ⇒ The process of learning is enhanced in its effectiveness and permanence when newly acquired information is integrated with previously accumulated experiences.
- ⇒ If the learning environment is rendered more enjoyable, students will be more inclined to learn effectively by perceiving learning as a secure endeavour.
- ⇒ It is evident that the acquisition of knowledge is a significant milestone that merits appropriate celebration.

The Quantum Learning Model has been developed to facilitate more comprehensive learning, by offering students academic and lifelong learning skills. In this sense, it can be argued that learning occurs in a more complex and enjoyable way compared to other methods. During the learning process, the Quantum Learning Model encourages the breaking down of information and its subsequent reassessment to create a whole, the

viewing of information from different angles, the posing of questions and the experience of a purposeful learning process. In this regard, the student is no longer merely an information recipient; they are also tasked with analysing information from diverse perspectives. This is facilitated by engaging multiple senses during the learning process. It is postulated that equipping learners with the ability to learn and imparting effective learning strategies can significantly contribute to the resolution of educational challenges. A substantial corpus of research has been published demonstrating the efficacy of the quantum learning in enhancing students academic achievement (Acat & Ay, 2014; Karamustafaoğlu, 2018). However, studies have also concluded that the quantum learning model is effective in developing positive attitudes towards lessons and learning (Barlas, 2002). Conversely, there have been studies suggesting that the quantum learning model has no effect on academic achievement (Ari & Alaca, 2015).

Hands-on Learning

Hands-on learning can be defined as a pedagogical approach involving experiential learning, learning by doing. In a broader sense, it can be defined as a learning method that involves the processes of observing, explaining, comprehending and thinking about an event or phenomenon with the help of tools created with simple materials that students use in their daily lives. Hands-on science learning (HSL) can be conceptualised as a pedagogical approach involving the use of materials, conducting experiments, exploring phenomena and formulating and testing hypotheses by students.



Figure 5. Contributions of HSL practices to students

The historical development of the method of learning by doing with simple materials that include extended experimental activities began in the 1910s with John Dewey's approach based on learning by doing, and with textbooks and laboratory manuals containing more practice-oriented arrangements (Kaptan, 1999). In experiments carried out

with simple materials from daily life, there is no need for a special laboratory environment or ready-made materials. The following list outlines some of the most notable features of this method:

- ⇒ The problems that are the subject of the activities are real-life problems.
- ⇒ Hands-on learning activities with simple materials will guide students through the process of scientific enquiry and support them in creating their own scientific knowledge as a result of their own scientific research.
- ⇒ The equipments and materials to be used in the activities consist of materials used in daily life and familiar to the student with all their properties, unlike the materials used in the laboratory.
- ⇒ These activities have been meticulously designed to foster students' scientific thinking, cultivate their aptitude for deriving knowledge through scientific processes, and facilitate their understanding of the scientific nature by engaging with it experientially.

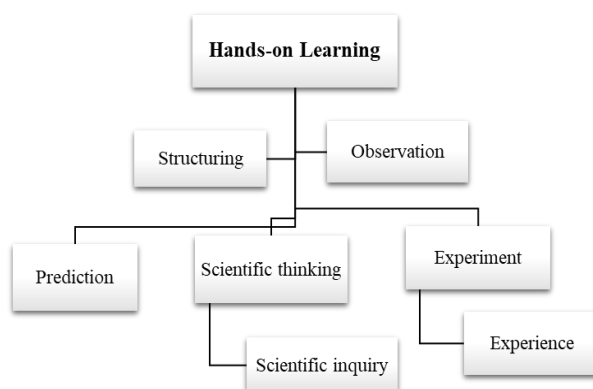


Figure 6. Skills gained by students through hands-on learning activities

As demonstrated in Figure 6, experiential learning activities have been shown to be effective in the development of skills such as structuring, observation, prediction, scientific thinking, experimentation, experience, and scientific inquiry. In the field of science education, the utilisation of simple materials empowers students to engage in practical experimentation, thereby facilitating the acquisition of scientific knowledge (Akgün, 2000). These activities play a pivotal role in fostering students' self-confidence, which stems from the ability to engage in hands-on learning and discovery. Furthermore, these activities play a crucial role in enhancing the conceptual understanding of students and fostering the development of connections between different scientific concepts, thereby enhancing their ability to transfer these concepts to new and varied situations.

In the contemporary context, a significant number of primary schools lack the facilities necessary for scientific experimentation, namely science laboratories. In schools that do possess such laboratories, the procurement of equipment is often hindered by financial constraints, resulting in either the complete absence of experimental activities or the limitation of demonstrations to a minimal scope. It is noteworthy that a substantial proportion of experiments that necessitate the use of costly materials can be effectively conducted by employing inexpensive and readily available resources, if such a course of action is deemed appropriate. This approach has been shown to encourage creativity, as evidenced by the development of apparatus such as a test tube from an exploded light bulb, a spirit stove from a medicine bottle, a barometer from a milk bottle and an equal-arm balance from tin cans. These experiments, utilising readily available, cost-effective, and pervasive materials, obviate the necessity for specialised equipment. This ensures the accessibility and reproducibility of the findings in both rural and urban educational settings. The utilisation of these simple materials in experimental activities is of paramount importance in the realm of science education, as it ensures equitable opportunities for all students to engage in scientific inquiry within the classroom environment. The utilisation of rudimentary materials in the execution of scientific experiments has been demonstrated to facilitate the cultivation of a multitude of science-related competencies in students. A study by Leung (2008) found that hands-on learning activities in science lessons had a positive effect on students' conceptual learning. Furthermore, it has been proposed that these experiments can be utilised in the instruction of the scientific method and the cultivation of problem-solving competencies (Jones et al., 2022).

Focus of the Study

The present study examined primary school students' science academic achievement, attitudes towards science and motivation to learn science within the context of two different learning conceptions. In addition, the retention of science learning status after the experimental application process was also examined. A review of the related literature revealed a paucity of research in this field, particularly at the primary school level. Consequently, this study was conducted within the scope of the science course at primary school level. A review of the extant literature reveals a preponderance of research on quantum learning model-based instruction and hands-on science activities in secondary schools (Çakır, 2013). This observation gave rise to the hypothesis that the paucity of

research in this field at the primary school level would be addressed by this study conducted at the fourth grade level. In this context, it is hypothesised that this study will contribute to the extant literature at primary school level. The objective of this study was to ascertain the impact of Quantum Learning Model-based instruction (QLM) and Hands-on Science Learning (HSL) on academic achievement in science, attitudes towards science, motivation to learn science, and the retention of learning in two distinct experimental groups. Consequently, the following research questions (RQs) were identified:

RQ1. What is the effect of QLM and HSL practices on students' academic achievement, attitudes towards science and motivation to learn science?

RQ2. Do the QLM and HSL activities have an impact on retention?

Method

Research Design

The aim of this study is to examine the effects of the Quantum Learning Model (QLM) and Hands-On Learning (HSL) methods on academic achievement, attitude, motivation, and knowledge retention. To this end, a pretest-posttest control group quasi-experimental design was used. As Fraenkel and Wallen (2006) have observed, the underlying principle that underpins the entirety of experimental studies is to "try certain things and systematically observe what happens". In accordance with this notion, the present study examined the impact of a science pedagogy approach that utilised the quantum learning model, hands-on science exercises and the current curriculum on the attitudes of fourth-year primary school pupils towards science lessons, their motivation to learn science, their academic achievement and the retention of learning. In two randomly selected experimental groups, science instruction was implemented based on quantum learning and hands-on learning activities. In the control group, the lessons were conducted in accordance with the current curriculum. The methodology employed in the study is outlined in Table 1.

Table 1. Experimental design of the research

Group/Test		Pre -Test	Process	Post -Test	Retention 1	Retention 2
Experimental 1	R	AT-AS-MS	QLM	AT-AS-MS	AT	AT
Experimental 2	R	AT-AS-MS	HSL	AT-AS-MS	AT	AT
Control	R	AT-AS-MS	Current Curriculum	AT-AS-MS	-	-

AT= Achievement Test AS= Attitude Scale MS= Motivation Scale QLM= Quantum Learning Model HSL= Hands-on Science Learning

As demonstrated in Table 1, achievement test (AT), attitude scale (AS) and motivation scale (MS) were administered to both groups as a pre-test prior to the initiation of the experimental process. In the Experimental group 1, QLM activities were incorporated into science lessons for a period of eight (8) weeks. During the eight-weeks experimental period, the HSL activities were employed in the teaching of science lessons within the Experimental group 2. In contrast, the control group was subject to the implementation of the current curriculum. The tests applied at the beginning were reapplied as post-tests at the end of the experimental process, and four (4) weeks after the end of the experimental process, the achievement test (AT) was reapplied as a retention test. The second retention test was administered eight (8) weeks after the post-test, thus enabling the effects of QLM and HSL activities on the retention of learning to be examined.

Study Group

The study group was selected from a public elementary school and consisted of 97 fourth-grade students (aged 9-10). The randomisation of subjects into experimental and control groups was a fundamental aspect of the study design. Consequently, each experimental group comprised 32 students. The control group comprised 33 students.

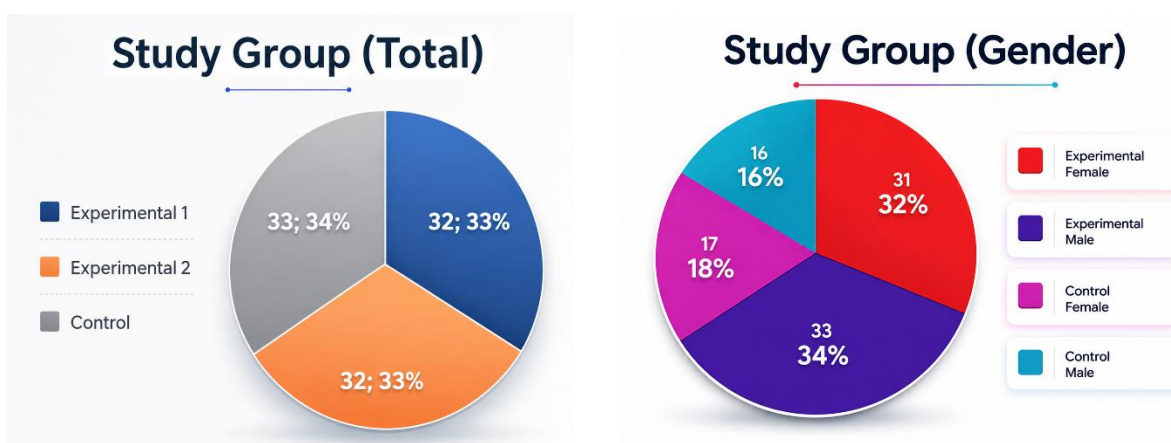


Figure 8. Descriptive data related to the study group

A detailed analysis of the data presented in Figure 8 reveals that the study was conducted with a total of 97 students. The experimental group comprised 64 students, of whom 32% were female and 34% were male, constituting 66% of the total study group. The control group (N= 33) constituted 34% of the study group. While the ratio of female participants in the control group to the total population of the study was 18%, the ratio of male participants was 16%. The school was selected from the Kastamonu provincial centre, taking into account the physical and socioeconomic potential of each school. This process

involved the implementation of 'typical sampling', a form of purposive sampling, to select the participating schools. Criterion sampling, a purposeful sampling method, was employed to determine the groups. The normality test was conducted in order to ascertain whether the data demonstrated a normal distribution. The Skewness and Kurtosis values of the data for each measurement tool are presented in Table 2.

Table 2. Normality test results of the data

Measurement						
Tools	N	<i>p</i>	Skewness	Kurtosis	Min.	Max.
AT	97	,00	.733	.059	3	10
AS	97	,00	.555	-.344	23	35
MS	97	,00	.273	-.466	22	35

In order to validate the hypothesis concerning the normality of the distribution of the research data, it is imperative to ascertain that the Skewness and Kurtosis values are within the specified range of -1.00 to +1.00. A thorough analysis of Table 2 reveals that these values are indeed within the prescribed range for the measurement tools. Considering these results, parametric tests were employed to analyse the data. Specifically, the academic achievement test, attitude scale, and motivation scale scores of the three groups were compared prior to the experimental process using a MANOVA test. The results of the analysis of MANOVA are given in Table 3 below.

Table 3. MANOVA results of the pre-test mean scores of students participating in the study regarding all measurement tools

Effect		λ	F	df1	df2	<i>p</i>	η^2
Groups	Wilks' Lambda	.955	.710 ^b	6,000	184,000	.642	.023

The MANOVA results on the scores of the three measurement tools (Table 3), which are the dependent variables of the study, indicate that there is no statistically significant difference between the scores of the control and experimental groups students on any variable, (λ)= 0.955, $F(6, 184)= .710^b$, $p > .05$. This result suggests that the students in both the experimental groups and one control group demonstrated similarities in terms of their science academic achievement, attitude towards science, and motivation to learn science at the commencement of the experimental process. Conversely, this outcome can be construed as indicative of the suitability of the measurement tools employed in this study for the specific research context.

Data Collection Tools

In order to assess the scientific accomplishment of the students, an “Academic Achievement Test” appropriate for the 'Let's Know Matter' unit was developed by the author. The 'Science Course Attitude Scale', also developed by the author, was utilised to ascertain students' attitudes towards the science course. Likewise, the 'Motivation Scale for Science Learning', also developed by the author, was utilised to ascertain students' motivation in relation to science learning. The data collection tools employed are outlined in Table 4 for reference.

Table 4. Data collection tools of this research

Measurement tools	Implementation Groups	Measurement tool models	In which phase it is used		
			Pre-Test	Post -Test	Post- implementations
Academic Achievement Test	QLM HSL Control	Quantitative	x	x	
Attitude Scale	QLM HSL Control	Quantitative	x	x	
Motivation Scale	QLM HSL Control	Quantitative	x	x	
Retention Tests	QLM HSL	Quantitative			2x

Academic Achievement Test: The 'Let's Know Matter Unit Achievement Test' (AT), developed by Uyanık (2014), is a multiple-choice test comprising 28 questions. The KR-20 reliability value of the test was calculated as 0.78, the total discrimination value as 0.48 and the total difficulty value as 0.51. Each correct answer is awarded a value of "1" point. In contrast, each incorrect answer was assigned a value of "0" points. Consequently, the maximum attainable score on the test was established as "28", while the lowest obtainable score was defined as "0". The KR-20 reliability value of the test was recalculated for the present study and determined to be 0.72. This determination led to the conclusion that the test would be deemed appropriate for implementation.

Science Attitude Scale: The 'Science Course Attitude Scale' (AS), which was developed by Uyanık (2014), was utilised to ascertain the attitudes of the students in the study group towards the Science course. The scale, which was developed as a three-point Likert-type scale with a single dimension, consists of 18 items. Given that the scale was to be

administered to fourth grade primary school students, it was deemed appropriate to develop the scale in 'triple likert' type instead of 'five likert' type. This decision was reached following consultation with experts in the field, who advised that the students' degree of agreement with the items be classified as 'never' (1), 'sometimes' (2) and 'always' (3) from negative to positive. The KMO value of the scale was calculated as .73. The Cronbach Alpha (α) reliability coefficient value of the scale was determined as .86.

Motivation Scale for Science Learning: The 'Motivation Scale for Science Learning' (MS), developed by Uyanık (2014), was utilised to ascertain the motivation of the students in the study group towards science learning. The scale, which was developed as a three-point Likert-type scale with a single dimension, consists of 19 items. The students' degree of agreement with the items was categorised as follows: "never" (1), "sometimes" (2), and "always" (3). The KMO value of the scale was calculated as .75. The Cronbach Alpha (α) reliability coefficient value of the scale was calculated as .87.

Implementation Processes

The Experimental Group 1 (QLM)

In the initial stage of the experimental implementation process, the classroom environment was organised in accordance with the quantum learning model (QLM). The desks were arranged in a cluster seating configuration to facilitate group work, and a science board was constructed where students could exhibit their individual or group work. The experimental implementation process involved students in the Experimental Group 1 performing activities prepared according to the principles of the QLM in the 'Let's Know Matter' unit. The following stages were observed during a sample lesson teaching practice in Experimental Group 1:

1. Capture Stage

The capture stage was initiated with the introduction of diverse materials, including nylon bags, dishwashing sponges, nails, pieces of wood, sawdust, glass cups, magnets, and a container of water, to capture students' attention and stimulate their curiosity. These items were placed on the teacher's desk and subsequently, the following inquiries were directed towards the students:

- ⇒ The relationship between the items on the table and the items on the floor was to be identified.

- ⇒ The items on the table were then thrown into the bucket one by one, and it was observed whether they all floated or sank.
- ⇒ The magnet was then tested to ascertain its ability to attract all the items on the table.
- ⇒ Students were asked to identify which materials attract water and which do not.

Following the articulation of these inquiries, it is asserted that the students will be enlightened as to the precise responses to the questions posed in this lesson, thereby facilitating a more profound comprehension of these substances.

2. Association Stage

The students were reminded of the qualitative properties of substances that can be felt through the sense organs that they had previously studied in third grade. The aim of this exercise was to enable the students to establish a connection between the new subject they would learn and their previous studies, thereby ensuring more permanent learning. The following questions were posed to reveal the students' prior knowledge:

- ⇒ What is matter?
- ⇒ With which senses can the properties of substances be determined?
- ⇒ What are the qualitative properties of substances that can be determined by sense organs?

The students were provided with hints and guidance on the subject during this stage, and they were also asked to create mind maps about the subject.

3. Labeling Stage

In the third stage, entitled 'Labeling', students were introduced to the concept of matter through the utilisation of animations and video presentations on the subject. These educational materials were displayed on a smart board in the classroom setting. Students were encouraged to periodically take notes by referencing the animations and videos. During this stage, 'Note Taking and Note Making' method was introduced to the students. This method is a significant component of quantum learning and is considered an essential skill in effective note-taking.

4. Demonstration Stage

At the inception of the experimental implementation, the classroom environment was configured in accordance with the cluster seating arrangement, with each cluster comprising four students. The "Let's Find the Characteristics of Matter" activity was conducted with

groups of four students. Subsequently, a worksheet on the subject was distributed to each group, and they were instructed to complete it collectively.

Activity Name: An Investigation into the Characteristics of Various Substances

Materials: A magnet, a plastic bag, a container filled with water, a paper towel, a paper clip, a dish sponge, a nail, sawdust, an eraser, an aluminium foil, a pencil, a plastic cap, a key, a coin and a pin.

Steps:1. The experiment was conducted in groups of four students. Initially, a small quantity of water was poured onto the table. Subsequently, the water was removed from the surface of the table using various materials, including a sponge, a napkin, aluminium foil, and a nylon bag.

Step:2. In another activity, students were instructed to bring a magnet close to nails, erasers, pencils, paper clips, wood shavings and pins.

Step:3. The students were then asked to put a coin, wood shavings, a plastic lid and a key into a bucket of water.

After these procedures, students were instructed to mark the appropriate spaces in the Table 5 below.

Table 5. Substances and their properties

Substance	Does not absorb water	Attracting water	Sinking in water	Floating on water	Attracted with magnet	Not attracted by magnet
Pencil						
Eraser						
Nail						
Key						
Aluminium foil						
Pin						
Napkin						
Paperclip						
Wood chips						
Coin						
Dish sponge						
Plastic cap						
Nylon bag						

5. Repetition Stage

In the fifth stage, entitled the 'Repetition Stage', students were tasked with producing a composition on the topic covered during the course. This was to be accomplished by means of the quantum writing method. Concurrently, a concise review of the course content was

furnished to the students. Furthermore, students were encouraged to reflect on the extent to which their perspective on quotidian experiences had been altered.

6. Celebration Stage

The studies, which were conducted within a positive classroom environment from the onset of the experimental process, were subsequently displayed on the Science board. The students were thanked for both their individual and group performances, and motivating words were said. Thereafter, the entire class was invited to applaud their own achievements and those of their peers. This culminated in the conclusion of the day's lesson with a celebratory phase.

In the Experimental Group 1 (QLM), the learning process was enhanced by the incorporation of mind maps, posters and pictures within the quantum learning model (QLM) during the experimental application process. The utilisation of note-taking and clustering techniques was instrumental in facilitating effective note-taking among students. Furthermore, the implementation of quantum reading, quantum writing and quantum memory techniques was pivotal in achieving the research objective. The outcomes of the students' individual and group works were showcased on activity boards. The utilisation of classical music during the activities had a positive impact on individual and group work, enhancing students' motivation for the lesson. In the control group, lessons were taught based on the existing curriculum, with the current class teacher conducting the lessons. Prior to and following the experimental process, academic achievement tests, the science attitude scale, and a motivation scale for learning science were administered to both the experimental and control groups. Following the administration of the post-test, the achievement test was reapplied to both groups as a retention test four (4) weeks later. The purpose of this procedure was to evaluate the students' retention and reminder levels. Eight (8) weeks after the post-test, the retention test was administered to both groups for a second time. This approach enabled the assessment of knowledge retention through repeated measurements.

The Experimental Group 2 (HSL)

The experimental implementation process was conducted over a period of eight weeks. During this process, applied science activities were utilised in the experimental group 2 to instruct the subjects in the Science course unit entitled "Let's Know Matter". The activities undertaken with applied science experiments in Experimental Group 2 are presented in Table 6.

Table 6. Hands-on science learning activities implemented in the experimental group 2

Subject	Materials
1. Matters and Structure	Piece of wood, small stone, paper, plastic bag, plastic bottle, tree bark, dishwashing sponge, glass cup.
2. Properties of Matter	Magnet, sawdust, pin, coin, nail, rubber band, paper clip, plastic cap, marble, chalk, glass bottle, tin can, piece of cloth, water, sponge, piece of cotton cloth.
3. States of Matter	Glass jar, water, small stones, paper, matches, a small cardboard box, a pencil.
4. Measurable Properties of Matter	Long stick, 1 meter rope, 1-liter plastic bottles, 2-liter plastic bottles, 1 liter of water, half a liter of oil, pebble, apple, orange, balloon, eraser, piece of wood.
5. Heat Exchange	Wall thermometer, two glasses of water, a glass of oil, a glass of ice, a 1-liter and a 2-liter plastic bottle, a glass of hot water.
6. Phase Change and Decomposition	1 candle, 3 metal containers, 5 spirit burners, tripod, half a liter of water, ice cubes, margarine, chocolate, granulated sugar, piece of bread.
7. Mixture and Solution	1 liter of water, 4 glass cups, plastic spoon, sand, a spoon of sugar, 50 ml. olive oil, a spoon of salt
8. Separation of Mixtures	Sieve, flour, sand, pebbles, straw, paper clip, pencil, eraser, chalk, 3 liters of water, a large plastic container, candle, straw, plastic lid, glass bottle, PET bottle, plastic spoon, porcelain spoon, ping-pong ball, plastic hair clip, wire hair clip, magnet, plastic funnel.

Throughout the experimental implementation process, which spanned a period of eight weeks, the activities delineated in Table 6 were executed by the experimental group 2. The implementation process for the 'Mixture and Solution' experiment, which is the experimental activity scheduled for week 7, is provided below as a sample of the activities carried out with simple materials:

In the teaching of the subject of mixture and solution, the students' prior knowledge was revealed through a series of exercises. Initially, the students were tasked with providing examples of substances that can and cannot be mixed. Subsequently, they were asked to provide examples of substances that can become invisible or cannot be when placed in water and stirred. Following this, the tools and materials to be used in the experiment were demonstrated to the students. Following the demonstration, a quantity of salt, granulated sugar, sand, and 50 ml of olive oil were added to the glasses containing water. The contents were then agitated with a spoon. The students were then invited to predict the changes that would occur in the glasses following this process. The responses provided by the students

were documented. Subsequent to the collection of the students' responses, a quantity of salt, sand, sugar, and 50 millilitres of olive oil were introduced into glass cups containing water. Thereafter, the contents of the glasses were agitated using a spoon. The students were permitted to make observations during the experiment. Symbolic visualisations of these experimental activities are presented in Figure 12, Figure 13, and Figure 14.



Figure 12. Dissolution of salt in water (example 1)

A little salt was introduced into a glass containing water, and the mixture was agitated with a spoon (Figure 12). Initially, the salt was discernible in the water, but over time, it became indistinguishable. Through this experiential learning process, students gained insight into the concept of a solution. This activity was observed by the students. Subsequent to the salt and water mixture experiment, the students were presented with sandy water and sugar water mixtures. The symbolic visualisations of these experiments are shown in Figure 13.



Figure 13. Sandy water and sugar water (example 2)

In the initial experiment, a quantity of sand was introduced into a glass receptacle containing water, and the mixture was agitated with a spoon for a designated period. Following the cessation of the stirring process, it was observed that the sand had settled to the bottom of the glass. In the subsequent experiment, a mixture of sugar and water was prepared (Figure 13). A quantity of sugar was added to a glass containing water, and following a period of agitation, it was observed that the sugar had become invisible in the water. During the experimental process, students were permitted to observe the experiments. Subsequent to these experiments, students were able to infer from experience that a mixture is constituted by sandy water, and that sugar water is a solution. Following these experiments, the olive oil and water mixture experiment (Figure 14) was conducted.



Figure 14. Mixture of olive oil and water (example 3)

A quantity of olive oil was added to a glass containing a small amount of water (Figure 14). It was observed that the olive oil added to the glass rose to the top of the water. Following these experiments, students were asked to compare their pre-experiments predictions with the results obtained after conducting the experiments. By observing the experimental procedures themselves, students were able to identify the correct answers. The experimental group participated in a series of eight weeks of hands-on science activities, which facilitated a learning-by-doing experience across all subjects within the science course.

Analysis of Data

The data were analysed with the SPSS 25.0 statistical package program. Given that the sample size of the study exceeded 30 ($N=97$), it was assumed that the data were normally distributed and the variances were homogeneous. Consequently, parametric tests were employed in the analyses. Consequently, two-factor ANOVA for repeated measures, and a

MANOVA analysis were chosen to analyse the data. The data were evaluated at a significance level of $*p < .05$.

Findings

The objective of the present study was to examine the impact of QLM and HSL implementations on students' scientific achievement, attitude, motivation, and retention in two distinct experimental groups. The results obtained from the study are presented in this section, respectively.

The first research question (RQ1) is to ascertain the impact of QLM and HSL activities on the academic achievement, attitude and motivation levels of the students in two distinct experimental groups. Within the scope of this question, the groups' academic achievement test, attitude and motivation scales post-test scores were subjected to multiple comparisons using MANOVA analysis. Following a rigorous testing process, it was ascertained that all assumptions inherent to the MANOVA analysis were duly verified. Consequently, the ensuing tables present the descriptive statistics, multivariate test results and Scheffe multiple comparison results for the dependent variables. Firstly, the data related to the descriptive statistics of the post-test results of all groups are presented in Table 7.

Table 7. Descriptive statistics of the post-test results of the groups

Dependent				
Variables	Groups	N	M	SD
AT	QLM	32	17,21	1,99
	HSL	32	21,93	2,42
	Control	33	10,63	2,02
AS	QLM	32	32,84	3,96
	HSL	32	36,21	3,57
	Control	33	27,72	2,77
MS	QLM	32	33,87	4,84
	HSL	32	42,21	3,61
	Control	33	28,21	3,14

AT= Achievement Test, AS= Attitude Scale, MS= Motivation Scale

Upon analysis of Table 7, it is evident that the mean score of the post-test academic achievement test for students subjected to QLM practices was $M=17,21$. In comparison, the mean score for students subjected to HSL practices was $M=21,93$, while the mean score for students in the control group was $M=10,63$.

The attitude scale post-test mean score of the students who were subjected to QLM applications was $M= 32,84$, the attitude scale mean score of the students who were subjected

to HSL applications was $M= 36,21$ and the attitude scale post-test mean score of the control group students was $M= 27,72$.

The motivation scale post-test mean score of the students who were subjected to QLM applications was $M= 33,87$, the motivation scale mean score of the students who were subjected to HSL applications was $M= 42,21$ and the motivation scale post-test mean score of the control group students was $M= 28,21$.

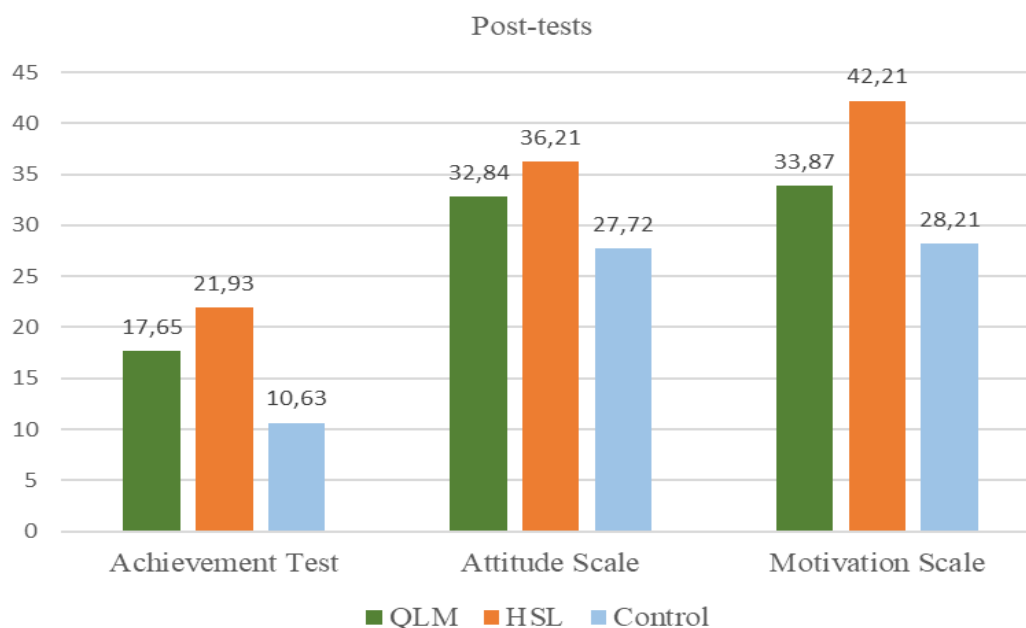


Figure 15. Graphical view of the post-test results of the groups

A thorough analysis of the mean scores obtained by the groups for the tests in Figure 15 reveals that the HSL group demonstrated the greatest increase in all three tests. Conversely, the control group, which received the current curriculum programme, exhibited the least increase. While the QLM group exhibited significant increases in all three test results, these increases were comparatively less substantial when compared to those observed in the HSL group.

In accordance with the findings of the conducted tests, the Wilks' Lambda (λ) value was considered in the MANOVA test statistic, as all the necessary assumptions for MANOVA were fulfilled. The multivariate test results for the groups are presented in Table 8.

Table 8. The results of the multivariate test for the groups

Effect		λ	F	df1	df2	p	η^2
Groups	Wilks' Lambda	.074	82.029 ^b	6,000	184,000	.000*	.728

* $p < .05$

As demonstrated in Table 8, which presents the results of the statistical analysis, a statistically significant difference was observed in the post-test scores of all groups following the experimental process. This is indicated by the (λ)= 0.074, $F(6, 184)= 82.029^b$, $*p<.05$ with a significance level of $*p <.05$. These results indicate that there is a substantial difference between the three groups with respect to the linear combination of dependent variables. The partial eta-square (η^2) value of .728 indicates that 72,8% of the variance in the dependent variables is attributable to the group variable.

In order to ascertain which post-test scores exhibited significant variation according to the group variable, the outcomes of tests of between-subjects effects were analysed. The values pertaining to these results are delineated in Table 9.

Table 9. Results of the between-subjects effects test on post-tests

Source	Dependent Variable	Type III		Mean Square	F	p	η^2
		Sum of Squares	df				
Groups	AT	2120,363	2	1060,181	203,079	.000*	.812
	AS	1190,221	2	595,110	49,582	.000*	.513
	MS	3219,846	2	1609,923	112,391	.000*	.705

* $p<.05$

A thorough analysis of Table 9 reveals that the ' p ' value for all dependent variables is less than .05. This result indicates that the post-test scores of all dependent variables demonstrate a significant difference in terms of the group variable. To ascertain which group exhibited these significant differences, the Scheffe test, a type of multiple comparison test, was employed. The results of the Scheffe test are presented in Table 10.

Table 10. Results of the Scheffe multiple comparison test

Dependent Variables	Group	Groups	Mean Difference	p
AT	QLM	HSL	-4,281	.000*
		Control	7,019	.000*
	HSL	QLM	4,281	.000*
		Control	11,301	.000*
	Control	QLM	-7,019	.000*
		HSL	-11,301	.000*
AS	QLM	HSL	-3,375	.001*
		Control	5,116	.000*
	HSL	QLM	3,375	.001*
		Control	8,491	.000*
	Control	QLM	-5,116	.000*

		HSL	-8,491	.000*
MS	QLM	HSL	-8,343	.000*
		Control	5,662	.000*
	HSL	QLM	8,343	.000*
		Control	14,006	.000*
	Control	QLM	-5,662	.000*
		HSL	-14,006	.000*

* $p < .05$

A thorough analysis of the results presented in Table 10 reveals a statistically significant discrepancy among all groups in relation to all dependent variables. A meticulous examination of the mean difference data further substantiates the efficacy of HSL as the most effective implementation in enhancing academic achievement, attitude, and motivation levels. Notably, HSL implementations demonstrate greater efficacy in science lessons when compared to QLM applications.

In the context of the second research question (RQ2), a comparison was made between the effects of QLM and HSL practices on retention. Therefore, a two-factor repeated measures ANOVA analysis was conducted. In the following analyses, the descriptive statistics of the academic achievement pre-test, post-test and retention tests of both experimental groups are presented in Table 11. Subsequently, the multivariate test results and within-subject contrast test results are presented in Table 12 and Table 13, respectively.

Table 11. Descriptive statistics related to academic achievement pretest-posttest and retention tests results of the groups

Dependent Variables	Groups	N	M	SD
Pre-test	QLM	32	5,96	1,53
	HSL	32	5,53	1,31
Post-test	QLM	32	17,21	1,99
	HSL	32	21,93	2,42
Retention Test 1	QLM	32	14,87	1,51
	HSL	32	20,53	1,84
Retention Test 2	QLM	32	11,81	1,35
	HSL	32	19,78	1,69

Upon analysis of Table 11, it is evident that the mean pre-test academic achievement test score of the students who were subjected to QLM practices was $M = 5,96$. Conversely, the mean pre-test score for students subjected to HSL practices was $M = 5,53$. The post-test academic achievement score of the students who were subjected to QLM practices was $M = 17,21$. Conversely, the mean post-test score for students subjected to HSL practices was $M = 21,93$. The mean retention test 1 score for students subjected to QLM practices was

M=14,87, while the mean score for students subjected to HSL practices was M=20,53. The mean retention test 2 score for students subjected to QLM practices was M=11,81, while the mean score for students subjected to HSL practices was M=19,78. In this context, Wilk's Lambda (λ) value was taken into consideration for the two-factor ANOVA test statistic in repeated measures. The results of the multivariate test for the groups are shown in Table 12.

Table 12. The results of the multivariate test for the groups

Effect		λ	F	df1	df2	p	ηp^2
Tests*Groups	Wilks' Lambda	.195	82.657 ^b	3,000	60,000	.000*	.805

* $p < .05$

In accordance with the results presented in Table 12, which demonstrate a statistically significant difference between the results of the repeated measures two-factor ANOVA of all groups, it can be concluded that the Wilks' Lambda (λ)= 0.195, $F(3, 60)= 82.657^b$, $*p < .05$ value is statistically significant. The partial eta-square (ηp^2) value of .805 indicates that 80,5% of the variance in the dependent variables can be attributed to the group variable. An analysis of within-subjects contrasts values was conducted to ascertain the specific test levels at which this significant difference was identified in relation to the group variable. The data pertaining to these values is presented in Table 13.

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Table 13. Test results of within-subject contrasts to determine retention

Source	Tests	Type III Sum of Squares	df	Mean Square	F	p	ηp^2
Tests*Groups	Pretest-Posttest	425,391		425,391	64,059	.000*	508
	Posttest-RT1	14,063		14,063	10,029	.002*	139
	RT1-RT2	85,563		85,563	36,871	.000*	373

* $p < .05$ RT1= First Retention Test, RT2= Second Retention Test

The results of within-subject contrasts tests in Table 13 demonstrate a significant difference between the results of all tests in terms of group variable. In order to ascertain which group is responsible for this difference, it is necessary to examine the descriptive statistics for all tests of the groups in Table 11 and the line graph in Figure 16.



Figure 16. Changes in academic achievement of QLM and HSL experimental groups

The results presented in Figure 16 demonstrate that, despite initial similarities in academic achievement amongst the groups, a subsequent divergence in academic achievement levels was observed upon the conclusion of the experimental process. It is evident that the academic achievement of the students in the Experimental group 2, where HSL practices were implemented, exhibited a significantly greater increase in comparison to the academic achievement of the other group, where QLM practices were employed. As illustrated in Figure 16, the retention test results of the groups also exhibited significant differences. This result lends further support to the hypothesis that HSL practices are more effective than QLM practices in facilitating permanent learning.

Discussion and Conclusion

The present study examined the effects of Quantum Learning Model (QLM) practices and Hands-on Science Learning (HSL) practices on students' academic achievement, attitudes, and motivation levels towards science courses, as well as their learning retention in primary school science courses. To facilitate this examination, the study was conducted in three distinct groups: Experimental group 1, in which QLM practices were administered; Experimental group 2, in which HSL practices were employed; and a Control group, in which the current curriculum was implemented. The study found that the three groups exhibited equivalent levels of academic achievement, attitude towards the science course, and motivation to learn science before the experimental procedure. However, the post-test results indicated the presence of statistically significant differences between the groups. The analyses revealed that both experimental groups exhibited positive differences from the

control group with regard to all dependent variables. This finding suggests that the QLM and HSL practices employed in the experimental groups were more effective than the current curriculum. As demonstrated in the studies of Acat and Ay (2014), Çakır (2013), and Yalçıntaş (2019), the impact of QLM implementations on students' academic achievement was investigated. The researchers concluded that QLM practices have a positive effect on students' academic achievement (Acat & Ay, 2014; Çakır, 2013; Yalçıntaş, 2019). In this respect, it can be concluded that the results of this study are consistent with the majority of the studies in the relevant literature. Conversely, Arı and Alaca's (2015) study concluded that there was no significant effect of QLM on enhancing academic achievement and attitude towards science. This outcome is not consistent with the results obtained in the present study.

As evidenced by the results of numerous studies in the relevant literature, the impact of HSL activities on students' science academic achievements, attitudes, and motivation levels has been thoroughly examined (Ateş & Eryılmaz, 2011; Leung, 2008). The conclusion of these studies indicated the efficacy of HSL practices in enhancing students' academic achievements, attitudes, and motivation levels. In this respect, the present study corroborates the findings of these previous studies and aligns with the extant literature on the subject. The initial objective of the study was to make a comparison between the effectiveness of QLM and HSL practices on students' science academic achievement, attitudes towards science and motivation towards learning science. Following a detailed analysis of the results, it was determined that HSL practices were more effective than QLM practices in terms of all dependent variables in a primary school fourth grade science course.

Another variable which was investigated in the study was that of retention. Following analysis of the retention test results of the experimental groups in which QLM and HSL implementations were made, it was determined that HSL implementations had a more permanent effect on science academic achievement. In the relevant literature, Arı and Alaca (2015) and Yalçıntaş (2019) compared QLM practices with the control group in their respective studies. The results indicated that QLM practices were more effective in ensuring retention than the current curriculum. Similarly, the present study found QLM practices to be more effective than the control group. However, when compared with the HSL group, HSL practices were found to be more effective in ensuring retention than QLM practices. In the contemporary era, characterised by the prevalence of science and technology, the

significance of science education has become increasingly evident. It is imperative to impart science education in a meaningful manner from an early age, as this can foster a deeper understanding of the subject. Individuals who acquire science knowledge through hands-on experience and experiential learning in their formative years tend to retain these memories more vividly throughout their lives.

This study has demonstrated that HSL activities are highly effective in promoting the retention of learning. In this context, it is recommended that HSL applications be utilised in science lessons, particularly at primary school level. In institutions lacking a laboratory within the school environment, or in schools with a laboratory but with inadequate materials, these HSL practices can be conducted with materials that are readily available in daily life. These experimental applications are met with great interest by young students, thereby enhancing their meaningful learning experience. This study sought to ascertain the impact of QLM and HSL interventions on the enhancement of academic achievement, the cultivation of positive attitudes towards science lessons, and the motivation to learn science in primary school fourth grade science lessons. The findings revealed a positive effect of both interventions on the aforementioned outcomes. However, a comparative analysis of the two learning practices indicated that HSL practices were more efficacious than QLM practices in primary school fourth grade science lessons. Furthermore, HSL practices contributed more to the realisation of permanent learning. This situation is briefly expressed visually in Figure 19.

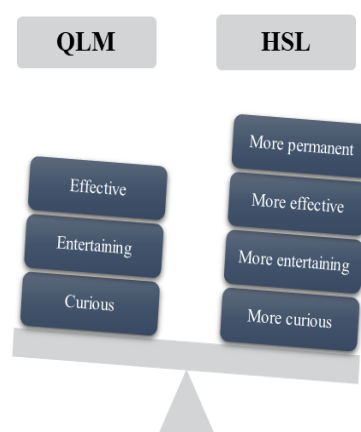


Figure 19. The evaluation of QLM and HSL applications in this research

As demonstrated in Figure 19, the findings of this study indicate that both QLM and HSL are indeed suitable for integration into science lessons and demonstrate the potential to facilitate active learning. However, the results of this study also suggest that HSL practices

demonstrate a higher level of effectiveness in primary school science lessons when compared to QLM practices. The results revealed that HSL practices exhibited superior efficacy in science lessons, a conclusion that may be attributed to numerous factors. The most fundamental reason may be that, in the learning process of HSL practices, students realise learning by doing and experiencing. Indeed, it is a well-known fact that the more senses individuals use in their learning processes, the more effective learning takes place. Another reason may be that HSL practices increase students' attitudes and motivation more. This study found a significant increase in students' motivation to learn science, which may have contributed to their academic success. Based on these results, it is recommended that learning-by-doing practices, involving simple experiments, be incorporated into HSL primary school science lessons. Future studies could involve a comparison of HSL with different teaching practices to further contribute to the existing literature.

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Since the data of this study were collected before March 2020, there is no ethics committee approval.

Author Contribution Statement

Gökhan UYANIK: *Literature review, methodology, experimental applications, statistical analyses, and interpretation of findings.*

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