The Effectiveness of an Educational Program Based on Realistic Mathematics on the Achievement and Productive Struggle of Fourth-Year Science Students

Asst. Prof. Dr. Laila Khalid Khudhair
University of Tikrit / College of Education for Pure Sciences / Department of Mathematics
Email: lelakhaled@tu.edu.iq

Abstract

The current research aimed to investigate the effectiveness of an educational program based on Realistic Mathematics in achievement and productive struggle among fourth-year science students. The researcher adopted the experimental method to implement the educational program on the research sample. The study population consisted of preparatory schools in Salah Al-Din Governorate, Iraq. The sample included 60 students from the fourth-year science class, divided into two groups: an experimental group (30 students) and a control group (30 students). An academic achievement test and a productive struggle scale were developed and reviewed by a panel of experts to ensure their validity. After confirming their suitability, both tools were applied to the sample. Statistical analysis was conducted using appropriate methods, and the results revealed the effectiveness of the educational program.
Keywords: Educational Program, Realistic Mathematics, Academic Achievement, Productive Struggle

Research Problem

Low academic achievement in mathematics is considered one of the common educational issues at the preparatory stage. This weakness becomes more evident among fourth-year science students due to the high level of understanding, analysis, and reasoning required at this level. Based on the researcher's experience of over twenty years in the field of teaching, a noticeable decline in achievement levels has been observed among many students in this stage, particularly in topics that rely on abstract and logical thinking.

Several studies have confirmed the existence of this weakness, including those by Al-Badrani (2025), Al-Laheebi (2025), and Al-Kubaissi (2025), all of which have pointed to a decline in students' academic achievement in mathematics. Furthermore, educational evidence indicates that these students often lack what is known as productive struggle skills — the skills that enhance a student's ability to persevere, overcome frustration, and continue trying despite challenges. Instead of persisting with understanding and repetition, some students tend to withdraw or rely on rote memorization, without truly grasping fundamental concepts. Traditional methods of teaching mathematics further contribute to the problem. These methods are often disconnected from students' real-life experiences, do not promote interaction or participation, and lack elements of engagement and realistic connection that help students comprehend abstract concepts. Hence, there is a need to adopt an educational program based on Realistic Mathematics, which aims to connect mathematical concepts to real-life situations and encourages students to construct knowledge gradually through meaningful life contexts, moving from reality to abstraction. Accordingly, the research question emerged:

"What is the effectiveness of an educational program based on Realistic Mathematics in academic achievement and productive struggle among fourth-year science students?"

Significance of the Study

The significance of this research emerges from two main perspectives:

Theoretical Aspect:

- The importance of this study lies in utilizing an educational program based on Realistic Mathematics in

teaching mathematics, due to its potential impact on improving the academic achievement of fourth-year science students.

- It may contribute to enhancing the knowledge of researchers and educators interested in mathematics teaching methods, especially those concerned with developing productive struggle skills among students.
- The study aligns with current global trends that emphasize the development of productive struggle skills in mathematics learners, considering these skills essential for academic and professional success.
- This research represents a scholarly response to modern educational trends that advocate for the adoption of interactive and realistic educational programs aimed at enhancing student performance and academic achievement.
- The study gains additional importance due to its focus on a crucial academic stage — fourth-year science students — which plays a pivotal role in shaping students' educational and professional futures.

Practical Aspect:

- Developing a productive struggle scale specifically for fourth-year science students, contributing to a reliable and scientific assessment of this skill.
- Designing an educational program based on Realistic Mathematics, tailored to meet the needs and abilities of fourth-year science students.
- Constructing an achievement test in mathematics aimed at fourth-year science students to measure the effectiveness of the educational program in enhancing their academic performance.

- Providing model lesson plans for teaching mathematics to fourth-year science students, based on real-life applications and grounded in Realistic Mathematics, thereby improving the effectiveness of instruction and linking it to students' everyday lives.
- The research findings may be used to improve students' academic achievement levels and enhance their ability to overcome challenges by developing productive struggle skills.

Research Objectives

The current study aimed to:

- Develop an educational program based on Realistic Mathematics to:
  - Investigate the effectiveness of the educational program in improving the academic achievement of fourth-year science students in mathematics.
  - Investigate the effectiveness of the educational program in enhancing productive struggle skills among fourth-year science students in mathematics.

Research Hypotheses

To achieve the research objectives, the following hypotheses were formulated:

- There was no statistically significant difference at the 0.05 level between the mean scores of the experimental group students, who are taught mathematics using the educational program based on Realistic Mathematics, and the mean scores of the control group students, who were taught the same subject using the conventional method, in the academic achievement test.

- There was no statistically significant difference at the 0.05 level between the mean scores of the experimental group students, who are taught mathematics using the educational program based on Realistic Mathematics, and the mean scores of the control group students, who were taught the same subject using the conventional method, in the post-productive struggle scale.
- There was no statistically significant difference at the 0.05 level between the pre- and post-test mean scores of the experimental group students, who are taught mathematics using the educational program based on Realistic Mathematics, on the productive struggle scale.

Research Delimitations

The current research was delimited to the following:

- Fourth-year science students in the city of Tikrit.
- Day schools for boys (intermediate and secondary) affiliated with the General Directorate of Education in Salah Al-Din Governorate, of Tikrit district.
- The first semester of the academic year (2024–2025).
- The first and second chapters of the prescribed mathematics textbook for fourth-year science students — Chapter One: Mathematical Logic and Chapter Two: Equations and Inequalities, 11th edition, issued by the General Directorate of Curricula, Ministry of Education, Republic of Iraq.

Definition of Terms

1. Effectiveness

- Masoudi et al. (2015) defined it as "Achieving the goal and the ability to accomplish it; it is the measure by which we recognize the performance of the teacher and

the learner in the learning process." (Masoudi et al., 2015: p. 54)

- Theoretical Definition of Effectiveness:
  - The degree of influence exerted by one or more independent variables on one or more dependent variables.
  - Operational Definition of Effectiveness:
  - The degree of positive change resulting from applying the educational program based on Realistic Mathematics to fourth-year science students was measured by the differences in academic achievement and productive struggle between the experimental and control groups

2. Educational Program

- Al-Nabit (2016) defined it as "A sequence or series of educational activities and tasks designed and organized to achieve predetermined educational objectives over a sustained period." (Al-Nabit, 2016: p. 22)
- Theoretical Definition of Educational Program: An integrated instructional system aimed at facilitating the learning and teaching processes. It consists of interrelated learning activities planned and organized in advance to reach specific educational goals. The program is delivered over a specific period in the form of sequential units, which include objectives, content, activities, assessment methods, instructional materials, and expected outcomes. It maintains a balance between planning, implementation, and evaluation.

- Operational Definition of Educational Program: A set of ten instructional sessions was designed by the researcher based on Realistic Mathematics principles. The sessions were built around meaningful real-life situations and were used as a starting point to teach mathematical concepts. The researcher delivers these sessions to the experimental group to improve their academic achievement in mathematics and enhance their productive struggle.

3. Realistic Mathematics

- •Khalil (2018) defined it as "A theory of teaching and learning mathematics that links mathematical education with real-world applications." (Khalil, 2018: p. 572)
- Theoretical Definition of Realistic Mathematics: A teaching approach based on the idea that mathematics is not just a set of abstract rules but a human activity that emerges from real-life situations and is understood through experimentation and interaction with the surrounding environment.
- Operational Definition of Realistic Mathematics:The application of Realistic Mathematics principles in teaching the topic of Mathematical Logic from the first chapter of the mathematics textbook for fourth-year science students. The researcher implemented this approach with the experimental group to enhance their academic achievement and develop productive struggle.

4. Academic Achievement

- Al-Saadi (2016) defined it as "The score or level of success achieved by the learner in a specific subject or the extent to which they have advanced in the educational field." (Al-Saadi, 2016: p. 15)

- Theoretical Definition of Academic Achievement: The mathematical concepts and skills students learns and their ability to apply them in problem-solving, as a result of participating in organized learning activities and responding to tasks that require specific answers.
- Operational Definition of Academic Achievement:The amount of mathematical knowledge and skills gained by fourth-year science students and their ability to apply mathematical logic concepts after receiving instruction through the educational program based on Realistic Mathematics. This was measured by the scores they obtained on the achievement test, which was prepared by the researcher for this purpose.

5. Productive Struggle

- Al-Manoufi (2022) defined it as "A student's attempt to complete a task or solve a challenging problem that initially appears beyond their ability, with no clear solution method, but remains within their potential."
- Theoretical Definition of Productive Struggle:The effort exerted by the learner when encountering mathematical tasks or problems that require deep thinking. This enhances conceptual understanding and promotes reasoning and explanation skills, helping students develop their logical and inferential abilities.
- Operational Definition of Productive Struggle:The degree of perseverance and effort shown by fourth-year science students in solving mathematical logic problems and connecting them to real-life situations after being taught by the researcher using the educational program based on Realistic Mathematics. measured using the Productive Struggle Scale prepared by the researcher, which included skills across three stages: before the lesson, during the lesson, and after the lesson.

Theoretical Framework and Previous Studies

Section One: Theoretical Framework

First: Educational Programs

An educational program is a comprehensive system and one of the most fundamental pillars of the educational process. It is offered to learners and includes several interrelated elements, such as educational objectives, content, teaching strategies and methods, and assessment techniques — all aiming to meet the needs of learners and society alike.

- Foundations for Constructing an Educational Program These foundations can be classified into five main domains:
  - Philosophical
  - Cognitive
  - Psychological
  - Social
  - Technological
- Stages of Educational Program Development : The development of an educational program goes through three main stages:
  - Planning Stage: Program planning begins with mental activities and, most importantly, thinking about how to build objectives and design the educational program. (Abu Hawij et al., 2000: p. 195)
  - Implementation Stage:The program is applied in the classroom using tools and educational materials that have been prepared in advance to ensure that all activities are carried out effectively and accurately. (Qatami, 2008: p. 146)

- Evaluation Stage : A crucial phase for determining the extent to which the program's objectives have been achieved and the effectiveness of the educational process components. Evaluation is continuous throughout all stages of the program and helps identify problems and areas for improvement. (Al-Adwan & Mohammad, 2011: p. 31)

- Principles of Educational Program Development Some of the main principles for developing educational programs include:
  - Aligning learner needs with societal needs.
  - Developing social skills such as cooperation, teamwork, and a sense of belonging to
  - Family and country.
  - Considering individual differences among learners.
  - Using diverse instructional materials that foster self-learning and innovation.
  - Strengthening the learner's relationship with their natural environment by providing opportunities to interact directly with tangible objects. (Al-Kannani, 2020: p. 6)

Second: Realistic Mathematics Education (RME)

- Origins of Realistic Mathematics Education (RME): Realistic Mathematics Education (RME) is an instructional theory with a unique philosophy for teaching and learning mathematics and designing educational materials. The concept originated at the Freudenthal Institute in the Netherlands as part of the country's educational reform movement. It began with the Wiskobas Project (Mathematics in Primary School) in 1968, initiated by Treffers, Fred Goffree, Edu

Wijdeveld, Van den Heuvel-Panhuizen, and others. RME views mathematics as a human activity and a social construct rather than a finished product. It is based on two main ideas:

- Mathematics should be related to reality — it must be familiar to students and connected to their daily lives. This relationship with the real world is not limited to tangible reality but extends to anything students perceive as real and meaningful. The term "Realistic" originates from the Dutch word "zich realiseren", which means "to imagine." Thus, RME includes any contexts, applications, or models that students can imagine as real or realistic, even if they involve abstract mathematical concepts placed in familiar settings.
- Mathematics is an activity — students can learn it through engagement and practice.(As-Sanai, 2023: pp. 262–263) RME is consistent with the principles of school mathematics outlined by the National Council of Teachers of Mathematics (NCTM) in the United States, which emphasize the need for students to play an active and central role in the learning process through the provision of mathematical tasks and situations. (Al-Khuzaim & Al-Ghamdi, 2020: p. 820)

Principles of Realistic Mathematics Education (RME)

- The Activity Principle: This principle emphasizes the active role of learners in constructing their mathematical knowledge, based on the understanding that mathematics is a human activity.
- The Reality Principle: Mathematics should begin with meaningful problem situations that are rooted in the learner's real-life experiences. It encourages learners to apply mathematics to solve everyday problems.

- The Level Principle: Learning should progress through levels of understanding in a gradual and structured manner.
- The Intertwining Principle: This refers to the interconnectedness and integration of different mathematical domains and topics.
- The Interaction Principle: Mathematics is seen as a collaborative activity involving the exchange of ideas, rather than being an isolated individual effort.
- The Guidance Principle: Teachers and instructional materials should guide students toward rediscovering mathematical concepts, encouraging inquiry and exploration. (Khalil et al., 2023: pp. 214–215)
- In her current research, the researcher adopted a selection of these principles — specifically: activity, reality, level, and intertwining — to build the educational program based on Realistic Mathematics for fourth-year science students.

Key Features of the RME Theory

- Real-life contexts are used as the starting point for mathematical learning.
- Students generate their knowledge, engage actively in the learning process, and integrate knowledge across various mathematical domains. (Hirza, 2014: p. 27)
- RME enhances students' mathematical productivity and their positive attitudes toward mathematics.
- It helps in developing students' problem-solving strategies.
- It fosters the growth of logical-mathematical thinking.
- It improves students' performance in statistics and overall academic achievement, while also strengthening their problem-solving skills. (Basuki, 2018: p. 69)

Third: Productive Struggle

Productive struggle represents a way of thinking that helps students attempt to understand new concepts and connect them to prior learning experiences. It reflects a meaningful cognitive challenge within the learning environment, encouraging perseverance in problem-solving. Productive struggle takes several forms in the classroom, including:

- Thinking deeply about the problem.
- Connecting prior knowledge to new tasks.
- Restarting the problem-solving process.
- Trying alternative approaches upon realizing an error. (Abdullah, 2024: p. 35)

The National Council of Teachers of Mathematics (NCTM, 2014) defines productive struggle as one of the core practices of effective teaching that improves mathematics classrooms and provides learners with valuable opportunities to engage in struggle, which is essential for learning mathematics. (Khalil, 2024: p. 72) Productive struggle involves the effort to understand something that is beyond the student's current level of comprehension. This struggle aids in learning mathematical concepts and procedures. (Vazquez, S. R., 2016: p. 179) It refers to students attempting to solve a challenging task or problem that appears to be initially beyond their abilities and lacks a clear solution method, yet remain within their potential. (Hiebert & Wearne, 2003: p. 3) Warshauer (2021: p. 89) describes productive struggle in mathematics as students' attempts to understand content that is not immediately apparent.

The researcher believes that productive struggle is the student's mental effort in confronting and solving difficult mathematical tasks.

A. The Importance of Productive Struggle in Learning Mathematics

- Creativity: Productive struggle allows students to be creative and express originality by solving problems in their way.
- Flexibility and Mastery: It promotes deeper understanding and mastery of mathematical learning.
- Conceptual Connections: Helps students connect major concepts to sub-concepts.
- Active Learning: Encourages students to take ownership of their learning. (Abdullah, 2024: p. 38)
- Perseverance: Effective teaching focuses on fostering perseverance through several practices:
  - Understanding and persisting in solving problems.
  - Constructing viable arguments and critiquing the reasoning of others.
  - Applying mathematics to real-life contexts.
  - Strategically using appropriate tools.
  - Identifying and using mathematical structure. (Sayed, 2022: pp. 198–199)

B. The Mathematics Teacher's Role in Supporting Productive Struggle

- Designing tasks as real-life problems to make them more understandable and motivating, while fostering a sense of familiarity among students.
- Clarifying learning objectives to help students invest effort and sustain focus.
- Formulating goals that support active student participation.

- Encouraging discussion and promoting meaningful interaction among students. (Abd El-Aal & Abd El-Aal, 2024: p. 226)

C. Features of Productive Struggle

- Productive struggle plays a significant role in supporting continuous learning and in building conceptual connections.
- Both productive success and productive failure create ideal learning environments, as they contribute to long-term deep conceptual understanding.
- Productive struggle reflects students' sustained engagement with high cognitive-demand tasks.
- Interaction between teacher and student influences whether cognitive demand is maintained or lowered during task performance. Through attempts to justify their responses, students resolve misconceptions and achieve deeper conceptual understanding.
- In cases of lower-level struggle, students may reach the correct answer with teacher or peer intervention. However, this can reduce the cognitive demand of the task, as the student begins to mirror the thinking of the teacher or peers. (Sayed, 2022: p. 200)

Part Two: Previous Studies Related to the Research Topic

A. Studies on Realistic Mathematics Education (RME)

1.Khalil (2018):

The study aimed to identify the effect of an instructional program based on the theory of Realistic Mathematics Education on mathematics achievement and attitudes toward mathematics among preparatory program students at Imam Muhammad bin Saud Islamic University. The quasi-experimental method was used, with a sample of

72 students. The tools included an achievement test and an attitude scale. The results showed a statistically significant difference in favor of the experimental group on both the achievement test and the attitude scale toward mathematics.

2.Khalil (2023):

This study aimed to explore the level of mathematics teachers' instructional practices in light of the principles of Realistic Mathematics Education. The research adopted a descriptive survey method with a sample of 70 male and female mathematics teachers in middle schools. The data collection tool was an observation checklist. The results revealed statistically significant differences in favor of female teachers.

B. Studies on Productive Struggle

1.Al-Harbi (2021):

The study aimed to develop a proposed instructional strategy to support productive struggle in mathematics learning and assess its effectiveness in developing mathematical proficiency among second intermediate students. It followed both qualitative and experimental methodologies with a two-group design. The sample consisted of 57 students. The tools included a mathematical proficiency test and a productive disposition scale. The results showed statistically significant differences in the posttest in favor of the experimental group.

2.Al-Qurashi (2024):

The study aimed to identify the impact of a proposed training program based on the VARK learning styles model in developing teachers' practices for supporting productive struggle among middle school mathematics teachers. It followed a quasi-experimental one-group pre-posttest design with a sample of 20 mathematics teachers. The tool

used was an observation checklist. The results showed statistically significant improvements in teachers' practices in the posttest.

Research Methodology and Procedures

First: Research Methodology

To achieve the objectives of this research, the researcher adopted the following approaches:

A. Descriptive Methodology

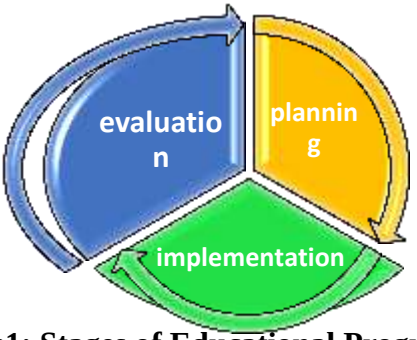
Used to review related literature, construct the theoretical framework, and examine the relationships between Realistic Mathematics Education, achievement, and productive struggle.

B. Experimental Methodology

The researcher adopted the experimental approach to test the effectiveness of the educational program based on Realistic Mathematics Education by measuring its impact on academic achievement and productive struggle.

Second: Educational Program Development

There are three main stages agreed upon in educational literature and previous studies when developing educational programs:



(Diagram1: Stages of Educational Program Development – Prepared by the Researcher)

A. Planning Stage

This is the foundational stage for developing educational programs and includes:

- 1.Defining Educational Objectives: A total of 58 objectives were developed based on Bloom's Taxonomy (Cognitive Domain): Remembering, Understanding, Applying, Analyzing, Evaluating, Creating.
- 2.Analyzing Students' Needs: Using tools such as interviews and questionnaires.
- 3.Selecting Educational Content: Topics included in the first and second units of the 4th-year science mathematics curriculum ("Mathematical Logic" and "Equations and Inequalities").
- 4.Preparing Instructional Plans: A total of 14 lesson plans were prepared, distributed across both the experimental and control groups.
- 5.Determining Teaching Strategies: Aligned with the principles of Realistic Mathematics Education.

B. Implementation Stage

At this stage, the educational program is applied in a real learning environment. This includes:

- 1.Presenting content using diverse methods (lectures, activities, practical applications).
- 2.Promoting interaction between the researcher and students.
- 3.Utilizing educational aids and instructional technologies.

C. Evaluation Stage

The evaluation process includes:

- Pre-Evaluation: Used to assess students' readiness and prior knowledge related to the topics.

- Formative Evaluation: Conducted during program implementation, following the teacher's guide, and includes:
  - Activity and exercise evaluation
  - Pre-lesson preparation assessment
  - Evaluation of group activities
  - Oral/written questioning
  - Feedback and reinforcement
- Final Evaluation: Conducted at the end of the program to measure the achievement of the learning objectives.

Third: Research Procedures

1.Experimental Design

The study adopted a quasi-experimental design with partial control, using a posttest for two groups (experimental and control), as shown in the figure below:

Instrument	Dependent variable	Independent variable	test	group
Achievement test Productive struggle scale	achievement Productive struggle	The educational program based on realistic mathematics	Productive struggle scale	Experimental
		Conventional method		Control

(Figure 1: the experimental design of the current research)

2. Research Population and Sample:

The research population consisted of fourth-year scientific stream students in daytime intermediate and secondary schools for boys during the 2024–2025 academic year, under the General Directorate of Education in Salah Al-Din / Tikrit Center. The researcher visited the

Planning Division at the Tikrit Education Department to review the schools. To implement the experiment, the researcher purposively selected Khalid Ibn Al-Walid Secondary School as the research sample for several reasons, including the school's proximity to the researcher's residence, which facilitated regular visits to monitor the mathematics teacher who implemented the experiment on the researcher's behalf. Additionally, the school's administration demonstrated cooperation and provided support, and the school included two fourth-grade scientific stream classes. Students who had previously failed were excluded from the experiment, as shown in Table 1.

Table 1

Distribution of Students in the Experimental and Control Groups

Number of students after exclusion	Number of excluded students	Number of students before exclusion	Section	Group
35	2	37	A	Exp.
35	2	38	B	Control

3. Equivalence of the Research Groups:

Equivalence was statistically established between the two groups (experimental and control) in several variables that could affect the results of the experiment, as follows:

a. Students' Age in Months:

The chronological age of students in both the experimental and control groups was calculated in months. The researcher prepared an information form for both groups and verified it against school records. The results showed that the computed t-value was lower than the tabulated t-value, indicating that there was no statistically significant difference at the (0.05) level. Thus, equivalence was achieved in this variable, as shown in Table (2).

b. Prior Academic Achievement:

The researcher obtained students' grades from the previous academic year for both groups from the school administration. The results showed that the calculated t-value was lower than the tabulated t-value, indicating no statistically significant difference at the (0.05) level. Thus, equivalence was achieved in this variable, as shown in Table (2).

c. Intelligence Scores:

The researcher administered the standardized Otis-Lennon School Ability Test (OLSAT), which is suitable for the Iraqi educational environment, to both groups before applying the experiment. The test consisted of 50 multiple-choice questions divided into 22 verbal items, 14 picture-based items, and 14 symbolic items. The results indicated that the calculated t-value was lower than the tabulated t-value, meaning no statistically significant difference at the (0.05) level. Thus, equivalence was achieved in this variable as well, as shown in Table (2).

Table (2)
T-test Results for the Equivalence Variables between the Experimental and Control Groups

Statistical Significance at 0.05	t. value		Control group (35)		Experimental group (35)		Group Variables
	tabulated	calculated	SD	Mean score	SD	Mean score	
Not statistically significant	2.00	0.415	4.05	193.20	3.40	193.57	Age
		0.138	16.72	72.91	16.18	72.37	Previous Year Grades
		0.242	5.723	31.66	6.23	31.44	IQ Scores

1.Parents' Educational Level:

The researcher obtained information about the educational level of the parents of the participants in both the experimental and control groups by distributing a

questionnaire to the students and cross-checking the data with school records. The educational levels were categorized as (Primary, Intermediate, Secondary, Diploma, and Bachelor's degree or higher).

The Chi-square test (χ^2) value calculated was less than the critical tabulated value at the 0.05 significance level, indicating no statistically significant difference between the two groups on this variable. Therefore, the two groups were considered equivalent in terms of parents' educational level, as shown in Table (3).

Table (3)
Chi-Square Test (χ^2) Results for Parents' Educational Level for the Experimental and Control Groups

Statistical significance0.05	X^2							Study group number	group
Not significant	Tabulated	calculated	Bachelor's	Diploma	Secondary	intermediate	Primary		
	9.488 Df= (4)	0.299	3	4	7	6	15	35	Exp. Father
			3	5	6	7	14	35	Father Control
		0.106	3	5	7	7	13	35	Mother Exp.
			3	5	8	7	12	35	Mother Control

4. Research Requirements

a. Development of the Educational Program:

The educational program was designed based on Realistic Mathematics Education (RME) principles, tailored to suit the research sample and the subject matter.

b. Content Organization:

The scientific content was selected from two chapters of the mathematics textbook for the fourth scientific grade:

- Chapter 1: Mathematical Logic
- Chapter 2: Equations and Inequalities

c. Formulation of Behavioral Objectives:

A total of 94 behavioral objectives were formulated according to Bloom's cognitive taxonomy levels: (Knowledge, Comprehension, Application, Analysis, Synthesis, Evaluation). Expert agreement on their validity exceeded 86%.

d. Preparation of Teaching Plans:

Teaching plans were developed for both the experimental and control groups based on the Realistic Mathematics Education (RME) approach. These plans were reviewed by experts in mathematics teaching methods, with more than 85% agreement on their appropriateness.

e. Preparation of Activities and Educational Media:

A set of educational activities and instructional media were prepared to support the program implementation.

f. Selection of Strategies:

Several instructional strategies aligned with the principles of Realistic Mathematics Education were selected after consultation with experts in mathematics education. Since RME does not rely on a single strategy and requires an open classroom environment, the following strategies were adopted:

- Real-Life Problem Solving
- Cooperative Learning
- Mathematical Modelling

5. Construction of the Research Tools

First: Achievement Test

The test was constructed following several steps:

- Defining the Test Objective and Number of Items:The test aimed to measure the academic achievement of fourth-grade scientific grade students in mathematics. It consisted of 20 multiple-choice items, each with four alternatives.
- Preparation of the Test Specification Table: A test specification table was developed based on the weight of the behavioral objectives, as shown in Table (4)

Table (4)

Table of Specifications (Achievement Test)

Total	Levels of Behavioral Objectives and their Weights						Content Weight	No. of Lessons	chapters
	evaluation	synthesis	Analysis	Application	Comprehension	Knowreuge			
	10%	10%	20%	15%	20%	25%			
8	1	1	1	2	2	2	38.1%	8	1
12	2	1	2	2	3	2	61.9%	13	2
20	3	2	3	4	5	4	100%	21	Total

3. Test Instructions:

The students' responses were graded by the researcher using the answer key (scoring rubric), assigning 5 marks for each correct answer and zero for each incorrect one. The final score totaled 100 points. Students were instructed not to leave any questions unanswered and not to select more than one answer per item. An illustrative example was provided to ensure clarity.

4. Test Validity:

Two types of validity were ensured:

- Face Validity: The test items were presented to a group of experts and specialists in mathematics teaching methods. Over 80% of them approved the items, with only minor adjustments made.
- Content Validity: The table of specifications served as an indicator of content validity. The test blueprint was reviewed by experts, confirming the alignment of items with learning objectives.

5. Pilot Testing:

•First Pilot Test:

After confirming face and content validity, a preliminary trial was conducted on a pilot sample of 30 students from the fourth scientific grade at Ibn Al-Mu'tam Secondary School for Boys, affiliated with the Salah Al-Din Directorate of Education / Tikrit Center. The aim was to assess clarity of instructions and items, and to estimate the average time needed for completion. The average time was 40 minutes, and the test was administered on Tuesday, December 3, 2024.

• Second Pilot Test:

Aimed at analyzing the test items, this was applied to another pilot sample of 50 students from the fourth scientific grade at Al-Furqan Secondary School for Boys, affiliated with the Salah Al-Din Directorate of Education / Tikrit Center. Test papers were scored and arranged in descending order to conduct statistical analyses. The top and bottom 27% of the papers were selected to represent the high and low groups. The following statistical analyses were conducted:

- •Item Difficulty Index: Calculated using the difficulty formula, with results ranging between 0.30 and 0.69, indicating acceptable difficulty.

- •Discrimination Index: Values ranged between 0.30 and 0.64, considered acceptable.
- •Distractor Effectiveness: Distractor analysis showed that most distractors had negative effectiveness, indicating functionality.
- •Test Reliability: Reliability was measured using Cronbach's Alpha, resulting in 0.85, which indicates high internal consistency.

Second: Productive Struggle Scale

Due to the absence of an appropriate existing tool to measure productive struggle suitable for the research sample, the researcher developed a customized scale. The steps of its construction were as follows:

- Purpose of the Scale:To assess productive struggle among fourth-grade scientific students in mathematics, particularly by observing their perseverance and engagement while learning topics related to mathematical logic.
- Determining the Dimensions of Productive Struggle:

Based on literature and studies on productive struggle in mathematics, such as Livy et al. (2018), Edwards (2018), Trinder & Hughes (2021), Abdullah (2024), and Khalil (2024), and after consulting mathematics education experts, the following dimensions were identified:

- Before the Lesson: Preparedness and readiness for the lesson.
- During the Lesson: Effort and perseverance during instruction.
- After the Lesson: Persistence in trying and continuing to learn.
- Item Development for Each Dimension:A total of 17 items were developed across the three dimensions:

- items for the first dimension (Before the Lesson),
- items for the second dimension (During the Lesson),
- items for the third dimension (After the Lesson).

Table (5)

Dimensions of Productive Struggle and Number of Items

NO. OF ITEMS	ITEMS	DIMENSIONS	NO
5	1 , 2 , 3 , 4 , 5	BEFORE THE LESSON (PREPAREDNESS)	1
7	6,7,8,9,10,11,12	DURING THE LESSON, (EFFORT AND PERSEVERANCE)	2
5	13,14,15,16,17	AFTER THE LESSON (PERSISTENCE AND CONTINUED LEARNING)	3
17	TOTAL		

Scoring and Interpretation of the Scale

The scale items included three response options: (Agree, Neutral, Disagree), with corresponding scores of (3, 2, 1). Accordingly, the overall score on the scale ranged from 17 to 51.

5. Validity of the Scale

Two types of validity were utilized, as follows:

- Face Validity: The researcher presented the initial version of the scale to experts and specialists in mathematics teaching methods to ensure that the items were relevant to the dimensions of productive struggle. The agreement rate among the reviewers exceeded 85%, with minor revisions made to some items.
- Construct Validity: Internal consistency was verified by examining the following:
  - Item-to-Total Correlation: Pearson correlation coefficients were calculated between each item and the

total score of the scale. The correlation coefficients ranged between (0.01 – 0.46), indicating that all items were acceptable. (See Appendix 1)

- Subscale-to-Total Correlation: Pearson correlation coefficients were calculated between the total score of each dimension and the overall score of the scale. (See Appendix 2)

6. First Pilot Application of the Scale

The Productive Struggle Scale was administered to a pilot sample of 30 fourth-year science stream students from Ibn Al-Mu'tam Secondary School for Boys (under the Salah Al-Din Directorate of Education, Tikrit) on Sunday, December 11, 2024. The purpose was to verify the clarity of the scale items and determine the average completion time, which was found to be 30 minutes.

7. Second Pilot Application of the Scale

The scale was administered to another pilot sample of 50 fourth-year science students from Al-Furqan Secondary School for Boys (Salah Al-Din Directorate of Education, Tikrit) on Sunday, December 12, 2024. After correcting the responses, the top and bottom 27% of the answer sheets were selected to represent the high and low groups. The following statistical analyses were conducted:

- Discriminative Power: The discriminative ability of the items was tested, and all items were found statistically significant, with discrimination values ranging from (2.546 – 9.279) at the (0.05) significance level. Thus, all items were deemed effective in distinguishing between students.
- Reliability: Cronbach's Alpha was used to determine internal consistency. The reliability coefficient was (0.88), indicating high reliability of the scale.

8. Experimental Procedures

The achievement test and the Productive Struggle Scale were administered to the study sample students at Khalid Ibn Al-Walid Secondary School on Sunday, December 15, 2024.

9. Statistical Tools

The Statistical Package for the Social Sciences (SPSS) was used for data analysis.

Presentation of Research Results

The results of this research will be presented based on its two hypotheses, followed by an interpretation.

First Hypothesis:

The first hypothesis states:

"There is no statistically significant difference at the 0.05 level between the mean scores of the experimental group students, who are taught mathematics using the Realistic Mathematics Education-based program, and the control group students, who are taught using the conventional method, in the achievement test."

To test this hypothesis, the researcher calculated the means and variances of the scores for both the experimental and control groups on the achievement test. An independent samples t-test was used to determine whether the difference between the means was statistically significant. The results are shown in Table (6).

Table (6)
t-test results for the experimental and control groups on the achievement test

Statistical significance at 0.05	t- value		Df	SD	mean	n.	Group
	tabulated	Calculated					
Statistically significant	2.00	9.399	58	7.239	85.07	30	Exp.
				9.159	65.03	30	Control

It is evident from Table 6 that the calculated t-value (9.399) is greater than the tabulated t-value (2.00) at the significance level of 0.05 with 58 degrees of freedom. Therefore, the null hypothesis is rejected, indicating a statistically significant difference in the achievement scores between the two groups in favor of the experimental group.

Interpretation of the First Hypothesis:

This result indicates that the educational program implemented by the researcher had a clear positive impact on enhancing the academic achievement of students in the experimental group compared to their peers in the control group who were not exposed to the program. This can be attributed to the use of active teaching methods within the program, the variety of activities and techniques employed, and the increase in students' motivation to learn. The program encouraged thinking and analysis rather than rote memorization, which helped students build a deeper understanding of mathematical concepts and better comprehend the content.

Second Hypothesis:

The second hypothesis stated:

"There is no statistically significant difference at the (0.05) level between the mean scores of the students in the experimental group, who are taught mathematics according to the educational program based on realistic mathematics, and the mean scores of the students in the control group, who are taught the same subject using the traditional method, in the post-productive struggle scale."

To test the validity of this hypothesis, the researcher calculated the mean and variance of the scores of both the experimental and control groups in the productive struggle scale. To determine the significance of the difference between the two means, the independent samples t-test was used. The results are shown in Table 7.

Table (7)
t-Test Results for the Experimental and Control Groups on the Post-Productive Struggle Scale

Statistical significance at 0.05	t-value		DF	Sd	Mean	N	group
	tabulated	Calculated					
Statistically significant	2.00	8.581	58	5.693	40.93	30	Exp.
				5.344	28.70	30	Control

Table (7) shows that the calculated t-value (8.581) is greater than the tabulated t-value (2.00) at the 0.05 significance level and 58 degrees of freedom. Therefore, there is a statistically significant difference between the scores of the experimental and control groups on the post-productive struggle scale in favor of the experimental group.

This result indicates that the instructional program based on Realistic Mathematics Education (RME) produced a noticeable and genuine improvement in students' understanding of logical concepts and their ability to apply inequalities, which in turn enhanced the productive struggle of fourth-grade science students. Productive struggle does not imply that students are suffering or frustrated; rather, it refers to the constructive cognitive effort students make when facing challenging learning tasks that slightly exceed their current understanding, yet are still attainable. It is a period in which students think deeply, experiment with different solutions, and learn from the mistakes they make along the way.

Hypothesis Three:

The third hypothesis stated that "There is no statistically significant difference at the 0.05 level between

the mean scores of the experimental group students who were taught mathematics according to the instructional program based on Realistic Mathematics Education in the pre-test and post-test of the productive struggle scale."

A paired-samples t-test was used to compare the mean scores of the experimental group students in the pre-application and post-application of the productive struggle scale. The results are shown in Table (8).

Table (8)
Means, standard deviations, and t-value of the experimental group scores on the productive struggle scale (pre-test and post-test)

Statistical significance at 0.05	t-value		DF	SD	Mean	N	Group
	Tabulated	Calculated					
Statistically significant	2.00	13.279	29	4.302	24.10	30	Pre-test
				5.693	40.93		Post-test

It is evident from Table (8) that the calculated t-value (13.279) exceeds the tabulated t-value (2.002) at the 0.05 level of significance and 29 degrees of freedom. This indicates the presence of statistically significant differences in means in favor of the post-test, which confirms the effectiveness of the instructional program in enhancing productive struggle among fourth-grade science students.

Interpretation of the Third Hypothesis Results:

The results suggest that the instructional program was effective in enhancing students' abilities to face academic challenges across different phases of the lesson, in alignment with the domains of productive struggle. Before the lesson, students demonstrated an increased ability to

mentally prepare themselves and activate prior knowledge to connect with new ideas. This reflects improved cognitive readiness skills and the building of a conceptual foundation before engaging with the lesson content.During the lesson, students actively engaged in trying out multiple solutions and correcting their mistakes by testing alternative strategies. This reflects growth in academic perseverance and cognitive flexibility, both of which are key indicators of productive struggle.After the lesson, students showed greater willingness to retry and review their steps, known as "restarting" the problem-solving process. This represents the essence of deep learning and a shift from reactive thinking to reflective problem-solving.

Accordingly, it can be concluded that the program provided a rich learning environment that supported linking prior and new knowledge (before the lesson), allowed room for error correction through various learning paths (during the lesson), and encouraged continuous thinking and retrying (after the lesson). This represents a qualitative shift from passive struggle—associated with frustration and hesitation—to productive struggle that is grounded in understanding, experimentation, and persistence. This aligns clearly with the four domains of productive struggle and indicates the program's profound educational impact on students' behavior within the learning context.

Determining the Effect Size:

To determine the effectiveness of the instructional program, the researcher relied on Eta squared (η^2) and Cohen's d equations. The results obtained are presented in Table (9) below:

Table (9)
Effect Size According to Research Variables

Interpretation of (d)	(d) value	Interpretation of (η^2)	Df	Eta squared (η^2)	Calculated t-value	Dependent variable	Independent variable
Very big	1.234	Very big	58	0.604	9.399	achievement	Educational program
Very big	1.127	Big	58	0.559	8.581	Productive struggle	Educational program

From Table (9), it is evident that the effect size (η^2) was large to very large, and according to Cohen's d, the effect size was very large. When compared to the standard benchmark values for Eta squared (η^2) and Cohen's d, this interpretation aligns with the thresholds shown in Table (10).

Table (10)
Benchmark Values for Effect Size

Large	Medium	Small	Metric
0.14	0.06	0.01	Eta squared (η^2)
0.80	0.50	0.20	Cohen's d

Conclusions

- Teaching mathematics based on the instructional program grounded in Realistic Mathematics Education (RME) increases the achievement of fourth-grade science stream students (experimental group), as confirmed by the results.
- Reorganizing the educational content according to the principles of RME, and integrating it with instructional activities, images, and illustrative diagrams, helped students better understand the topics in Chapters One and Two, leading to deeper and more comprehensive learning, which in turn improved their academic achievement.

Recommendations

- Organizing training courses for mathematics teachers on how to implement instructional programs—particularly those based on Realistic Mathematics Education—in teaching mathematics to fourth-grade science students.
- Drawing the attention of curriculum designers and textbook authors at all educational levels to the importance of considering Realistic Mathematics Education theory and its potential integration into suitable instructional programs.
- Mathematics teachers can benefit from these findings to design classroom activities that encourage students to think deeply while solving problems and persist through challenges instead of giving up.

Suggestions for Future Research

- The effectiveness of a training program based on Realistic Mathematics Education in developing coordinative thinking skills among middle school mathematics teachers.
- The impact of Realistic Mathematics Education strategies on the achievement and development of analytical thinking among second-grade intermediate students.

References

Arabic References

- Abu Huwaij, M., et al. (2000). Contemporary educational curricula: Concepts, elements, foundations, and processes (1st ed.). Dar Al-Nasher.
- Al-Badrani, A. M. A. R. (2025). The effectiveness of a teaching strategy supported by evaluative thinking skills on the achievement levels of fourth grade science female students and improving their mathematical beliefs (Unpublished master's thesis). University of Mosul, College of Education for Pure Sciences, Iraq.

- Al-Harbi, F. B. G. (2021). A proposed teaching strategy to support productive struggle in learning mathematics and its effectiveness in developing mathematical proficiency among second intermediate grade students (Doctoral dissertation). Qassim University, College of Education, Saudi Arabia.
- Al-Khalidi, A. M. (2008). The psychology of differences and scientific excellence (1st ed.). Dar Wael.
- Al-Khuzaim, K. M., & Al-Ghamdi, M. F. (2020). A proposed model for teaching mathematics in primary school in light of modern trends in mathematics education. In Conference on Modern Trends in Educational Sciences (pp. 791–820).
- Khalil, I. B. H., et al. (2023). Mathematics teachers' instructional practices in light of realistic mathematics education principles. Journal of the College of Education – University of Bisha, 3(3).
- Khalil, Y. F. M. (2018). The effect of an instructional program based on realistic mathematics education theory on the level of mathematical achievement and students' attitudes towards mathematics. Journal of the College of Education – Al-Azhar University, (179), Part 2.
- Khalil, I. B. H. (2024). The effectiveness of an educational program in developing mathematical achievement and productive struggle among intermediate students. International Journal of Educational Research, 48(1), 66–98.
- Dulaib, A. B. H. (2021). The impact of the Julai model on the achievement of fourth literary grade students in sociology and the development of their metacognitive thinking (Unpublished master's thesis). Tikrit University, College of Education for Humanities, Iraq.
- Al-Saadi, H. K. (2016). The effective teacher and their teaching strategies and models (1st ed.). Al-Yamamah Press, Baghdad.
- Sayed, H. M. S. (2022). Using GeoGebra to develop productive struggle and deep understanding in the geometry and measurement unit among first preparatory grade students in Assiut Governorate. Mathematics Education Journal (Tarbawiat Al-Riyadiyat), 25(2), Part 1.
- Al-Sanai, F. A. S. (2023). An instructional design in calculus based on the realistic mathematics education (RME) approach and

its effect on students' attitudes towards mathematics. Sana'a University Journal of Basic Sciences.
- Abdel Aal, H. M. M., & Abdel Aal, M. S. A. A. (2024). A program based on experiential learning to develop the ability to support productive struggle in mathematics and cognitive agility among pre-service teachers. Mathematics Education Journal (Tarbawiat Al-Riyadiyat), 22(3), Part 1.
- Abdullah, A. M. G. (2024). Using the pentagram strategy in mathematics teaching to develop logical-mathematical intelligence and productive struggle among preparatory students. Mathematics Education Journal (Tarbawiat Al-Riyadiyat), 27(2), Part 2.
- Al-Adwan, Z. S., & Al-Hawamdeh, M. F. (2011). Instructional design: Between theory and application. Dar Al-Maseera.
- Al-Qurashi, A. A., & Al-Shahri, S. M. (2024). The effect of a proposed training program based on the VARK model of learning styles in developing practices that support productive struggle among intermediate mathematics teachers. Journal of Educational Sciences and Human Studies, (14).
- Qatami, Y. M. (2008). Instructional design. Dar Al-Fikr.
- Al-Kubaissi, M. I. R. (2025). The effectiveness of a teaching strategy based on transformative learning theory on achievement and divergent thinking skills among fourth grade science students in mathematics (Unpublished master's thesis). University of Baghdad, College of Education for Pure Sciences – Ibn Al-Haytham.
- Al-Kinani, S. K. J. (2020). Educational programs and the modern trends they are based on and their strategies: A theoretical, cognitive, and applied vision. Al-Yamamah Publishing House.
- Kanaan, A. S. (2018). The effectiveness of using the realistic mathematics education (RME) approach in acquiring mathematical concepts among eighth grade students (Unpublished doctoral dissertation). Yarmouk University, College of Education.
- Al-Laheebi, Z. N. H. M. (2025). The effect of a proposed strategy based on CCSSM mathematical practice standards on the achievement and skillful thinking of fourth grade science students in mathematics (Unpublished master's thesis). University of Mosul, College of Education for Pure Sciences, Iraq.

- Al-Masoudi, M. H., et al. (2015). Curricula and teaching methods in the balance of teaching (1st ed.). Al-Ridwan Publishing, Amman.
- Al-Manoufi, S. J., & Al-Muth'im, K. A. (2022, January 14). Supporting productive struggle in learning mathematics. Egyptian Association for Mathematics Education – Workshop No. 6. https://cutt.us/pWe2Q
- Al-Nabit, S. M. (2016). Concepts and terminologies used in education, training, research, and development. Ministry of Development Planning and Statistics.

Foreign References

- Basuki, W. A., & Wijaya, A. (2018, September). The development of student worksheet based on realistic mathematics education. In Journal of Physics:Conference Series,
- Hiebert, J. & Wearne, D. (2003). Developing understanding through problem solving. Teaching mathematics through problem solving: Grades 6(12), 1 3-14
- Hirza, B., Kusumah, Y., Darhim, D., & Zulkardi, D. (2014). Improving Intuition Skills with Realistic Mathematics Education. Indonesian MathematicalSociety Journal on Mathematics Education, 5(1), 27-34. DOI: http://dx.doi.
- org/10.22342/jme.5.1.1446.27-34
- Vazquez, S. R. (2016). Parental Beliefs on the Efficacy of Productive Struggle and their Relation to Homework-helping Behavior (Unpublished Master Thesis). University of alifornia, Los Angeles.
- Warshauer, K., Starkey, C., Herrera, A., & Smith, S. (2021). Developing prospective teachers' noticing and notions of productive struggle with video analysis in a mathematics content course. Journal of Mathematics Teacher Education, 24, 89–121. https://cutt.us/UM2rr
- El-ahwal Marwa Nabil, Amir Shahin,2020 : Using video-Based on Tasks for Improving Mathematical Practice and supporting the productive struggle in Learning Math among Student Teachers In the Faculty of Education, International Journal of Instructional Technology and Educational Studies (IJITES) ISSN (Print): 2682-3918 - ISSN (online): 2682-3926 Volume1 / Issue1, April, 2020

Appendix (1):

Correlation Coefficient of Each Item with the Total Score of the Productive Struggle Scale

Correlation Coefficient	Item No.	Correlation Coefficient	Item No.
0.11	9	0.01	١
0.05	10	0.26	٢
0.43	11	0.38	٣
0.46	12	0.26	٤
0.17	13	0.20	٥
0.08	14	0.34	٦
0.21	15	0.47	٧
0.33	16	0.37	٨
0.11	17		

Appendix (2)

Correlation Coefficients Between the Total Score of Each Domain and the Overall Score of the Productive Struggle Scale

CORRELATION COEFFICIENTS	DOMAIN	NO.
0.618	BEFORE THE LESSON	١
0.706	DURING THE LESSON	٢
٠.٥٥١	AFTER THE LESSON	٣

***