The Effectiveness of Teaching Mechanics Using Practical Experiments in Developing Strategic Competence and Design Thinking for STEM School Students

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Abstract
The research aimed to identify the effectiveness of teaching the mechanics curriculum using practical experiments in developing strategic competence and design thinking among STEM school students. It was applied on a group consisted of (40) first year secondary school students, that was divided into (21) experimental group students and (19) students as a control group, A number of materials and tools were provided, including a list of design thinking skills, strategic competence, student's book containing the lessons of the mechanics syllabus scheduled for first-year secondary school students in the first semester after reformulating it according to practical experiments, teacher's guide for teaching the mechanics course using practical experiments, and the research tools, design thinking test, design thinking scale, and the strategic competence test, The results of the research revealed the effectiveness of practical experiments in developing design thinking and strategic competence among first-year secondary school students in STEM schools.
Keywords: practical experiences - STEM schools - design thinking - strategic competence.

Introduction

The rapid advancements in the modern era have brought significant changes to our daily lives. New technologies like artificial intelligence and the Internet of Things have made work more efficient. Additionally, progress in the fields of health and energy is helping to improve our lives overall. However, there are new challenges that require us to adapt to the continuous changes. While problem-solving abilities in mathematics are essential for success in the twenty-first century, many learners who struggle with mathematics do not develop these skills throughout their primary grades (Xin, 2019)

Mathematics, as an abstract science, is basically knowledge organized in a structure which has its origins, organization, structure and sequence, starting with incomplete knowledge until it gets integrated and reaches generalizations and results that depend on the generation of ideas and mathematical structures reflecting creativity, imaginativeness and intuition. (Abu-Zina, 2010, 17)

In teaching Mathematics, teachers aim to help students achieve certain mathematical skills. Therefore, teachers need to design learning activities that enable students to build their abilities. Activity that builds the students' ability can be done through giving non-routine problem. Non-routine problems are issues that do not use the usual steps, procedures, and algorithms to solve them. They challenge the students' mind and are not automatically known how to solve it.

The teaching and learning process is a complex one that involves many aspects, which contribute to its success. One of these aspects is the method of delivery and practices used in the classroom by the instructor. The focus of our study is to highlight the importance of combining theoretical and practical work in the educational process, specifically. (Sshana & Abulibdeh, 2020, 200)

Mathematics has a major role in the upbringing of successive generations through the mathematical concepts, relationships and skills it contains, especially since the objectives of teaching mathematics in its various branches, especially (mechanics). It facilitates a deep understanding of mechanics and helps students increase academic achievement

Basic mechanics forms the basis of multi-disciplines, and experiment is an important part of building a perfect teaching system of basic mechanics, which not only enables students to better understand the frontier dynamics of basic mechanics in multiple disciplines, but also promote and improve their interest in learning with an independent exploration spirit. (Zhang at el.,2018)

Design thinking is a process of using empathy, group ideation or brainstorming, prototyping, and testing to solve problems and create new products. Teachers have started to integrate DT into their classroom pedagogy. As more teachers and schools look for new problem-solving strategies, understanding the experience of the teachers' using DT is important. (Painter, 2018,2).The importance of design thinking has indeed been recognized in school education recently, especially in the current movement of STEM school. (Honey et al. 2014; NGSS Lead States, 2013)

Strategic competence helps students to apply the right strategy to find solutions to a problem. Strategic competence required students to monitor progress and develop alternative plans if the strategies used are predicted less effective (Kilpatrick,2001)

It is imperative that school curricula and instruction integrate design in students 'subject content learning, not just in engineering and technology but also in other STEM subjects and beyond and help foster their design intuition and thinking early on (e.g., Center for Childhood Creativity ,2018; Early Childhood STEM Working Group ,2017).

So, practical experiments emphasize the importance of providing students with design thinking skills, competence strategy and the ability to face life problems. Therefore, many institutions and organizations that are concerned with Developing the process of teaching and learning mathematics and improving the level of students in it by using practical experiments.

The pilot study

To get a documented idea about the students' performance in design thinking and Strategic Competence in Mechanics Syllabus, the researcher administered Design Thinking & Strategic Competence test on 20 students from Sharqia STEM School institute as a part of his pilot study to identify the actual level of students in design thinking and Strategic Competence in Mechanics Syllabus. The test included the five design thinking skills, which are (Empathy, define, ideate, prototype, and test) Results showed the average score of the pilot group was (16.42) degrees, with percentage of (28.05%), which is a low percentage, which indicated to the low and weak level of design thinking skills among students. The scale of design thinking included the same five previous skills, Results showed the average score of the pilot group was (45.25) degrees, with percentage of (32.45%), which is a low percentage, which indicated to the low and weak level of design thinking skills among students.

Finally, applied Strategic efficiency test which included six indicators (Formulates a mathematical problem based on a set of data, Represents mathematical problems with a diagram or chart, Solves mathematical problems in many ways, Creates a similar mathematical problem to a given one, It identifies the important givens in the problem and ignore the excess givens, and Proposes alternative solutions to incorrect solutions) Results showed The average score of the pilot group was (18.23) degrees, with percentage of (31.12%), which is a low percentage, which indicated To the low and weak level of Strategic efficiency indicators among students.

The researcher reached to the low level of first year secondary students in STEM schools in design thinking skills and strategic competence, which gave the researcher the opportunity to use practical experiences to teach the mechanics curriculum, train them in design thinking in an innovative way, and learn about practical experiences and how to use them in solving problems. Problems, and accordingly, the current research sought to develop design thinking skills and strategic competence using practical experiments to teach the mechanics curriculum to first year secondary students in STEM schools.

Statement of the problem

Considering the review of the related literature, results of the pilot study and the researcher’s experience in teaching STEM School, the problem of the present study could be identified in the weak performance of first year secondary stage students' Design Thinking and Strategic Competence in Mechanics Syllabus This may be due to the insufficiency of the Experimentally activities and teaching techniques. Consequently, the present study aimed at The Effectiveness of Teaching Mechanics Syllabus.

Questions of the Study

1- What are the appropriate design thinking skills required for first-year secondary STEM school students?
2- What are the appropriate competence strategy skills required for first-year secondary STEM school students?
3- What is the proposed prospective for using practical experiments to teach mechanics syllabus for the first year of secondary in STEM schools?

4- What is the effectiveness of using practical experiments in teaching the mechanics syllabus to develop design thinking skills among STEM school students?
5- What is the effectiveness of using practical experiments in teaching the mechanical syllabus to develop competence strategy skills among STEM school students?

Hypotheses of the Study

1- There is a statistically significant difference at $\alpha \leq (0.05)$ between the scores means of the experimental and the control group students on the post applied design thinking test in favor of the experimental group
2- There is a statistically significant difference at $\alpha \leq (0.05)$ between the scores means of the experimental and the control group students on the post applied competence strategy test in favor of the experimental group

Research Objectives:

1. To describe the design thinking skills that should be possessed by first-year high school students in STEM schools.
2. To describe the strategic competence indicators that should be possessed by first-year high school students in STEM schools.
3. To explain the reasons for the lack of interest in design thinking and strategic competence in teaching the mechanics curriculum using practical experiments for first-year high school students in STEM schools and the need for students to develop these skills.
4. To describe and interpret the nature of the correlation between mastering design thinking skills and understanding strategic competence in the mechanics' curriculum for first-year high school students in STEM schools.

Importance of the research:

For Teachers: Understanding design thinking skills, strategic competence, and how to develop them through practical experiments for teaching Mechanics to high school students at STEM schools. Also, familiarizing yourself with modern approaches, methods, and teaching strategies relied upon in practical experiments to enhance design thinking skills and strategic competence.

For Curriculum Planners: Utilizing the prepared teacher's guide based on practical experiment usage in teaching Mechanics to plan Mathematics curriculum, and creating various exercises that foster design thinking skills and strategic competence.

For Researchers: Utilizing the research materials and tools provided by the researcher, including the teacher's guide, design thinking skills assessment, and strategic competence test, based on practical experiments.

Research Variables:

1. Independent Variable: Practical experiments.
2. Dependent Variables: Design thinking and Strategic competence.

Research Limitations

1. A group of the first-year secondary students from Dakahlia STEM school at Gamassa City.
2. Five design thinking skills (empathy – defined- ideate- prototype - test).
3. Six competence strategy indictors
4. The first semester of the academic year 2023/2024.
5. The practical experiment for teaching in the first term.

Literature review

Practical Experiments

Basic mechanics forms the basis of multi-disciplines, and experiment is an important part of building a perfect teaching system of basic mechanics, which not only enables students to better understand the frontier dynamics of basic mechanics in multi-disciplines, but also promote and improve their interest in learning with an independent exploration spirit. (Zhang at el.,2018)

Practical work has been able to promote students' positive attitudes and enhance motivation for effective learning in science as described by Okam and Zakari (2017). Consequently, a positive attitude toward the importance of practical work meaningfully affects students' achievement in science (Hinneh, 2017).

Under the new situation, undergraduate education is increasingly required to develop a modular and multi-level experimental teaching system from foundation to synthesis, from theory to application and innovation. (Dong at el.,2020)

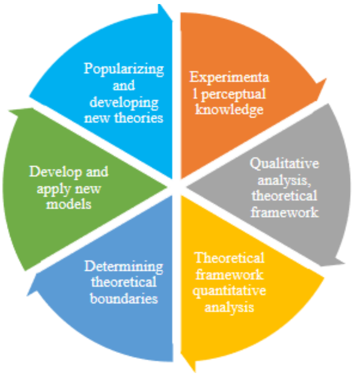
Experimental teaching has really become an important part and necessary means to cultivate students' experimental skills and innovative ability, and then achieve the goal of improving students' design thinking and innovation ability in scientific research. (Zhao at el., 2020)

Basic Principles for Designing an Experimental Teaching System for Basic Mechanics in Multi-Disciplines are: (Zhao, 2021).

1. Multidisciplinary Integration: Develop a systematic teaching system for material and vibration mechanics, considering course progression and planning comprehensive experimental projects.

2. Multiple Levels: Design experiments to address different student abilities across six levels: perceptual knowledge, qualitative analysis, theoretical framework, boundary conditions, model application, and theory development.
3. Modular Design: Create open, modular experimental projects to expand functionality and foster student creativity.
4. Resource Sharing: Use interchangeable experimental devices for resource sharing and implement both online and offline teaching, including virtual simulations.

Figure (1) The Multi-Level Design of Experimental Project



Study of Zhao (2021) aimed to improve the teaching system of basic mechanics experiments to support building a high-level university and training excellent engineers. The result is Principles, practical measures, and an assessment index system were explored to design a multidisciplinary teaching system for basic mechanics experiments, helping students actively analyze and solve problems and deepen their understanding of professional knowledge.

STEM approach

The science, technology, engineering, and mathematics (STEM) approach is an interface that removes the barriers between the four branches of knowledge: science, technology, engineering, and mathematics and integrates them, as it provides students with learning experiences from real-life situations rather than providing separate, disjointed facts. It is an innovative method in Teaching affects learning in a positive way (Fan & Ritz, 2014)

Fioriello (2010, 2010) defines STEM as an approach to education that works to integrate science, technology, engineering, and mathematics by employing teaching methods and strategies based on problem solving, projects, and discovery learning. Implementing the STEM approach requires student participation and interaction. Actively find solutions to specific situations and problems. National Research Council(16, 2011) defines it as empowerment The student, from the beginning of his education in the primary stage, learns these sciences and demonstrates the interconnection and interaction between them, through activities and direct experiences, whether inside or outside school, with an emphasis on developing communication and work skills Teamwork, critical and creative thinking skills.

From the researcher point of view, STEM approach integrates Science, Technology, Engineering, and Mathematics education, emphasizing design thinking—translating ideas into innovative solutions—and strategic competence, organizing efforts effectively towards achieving specific goals through critical and innovative problem-solving.

Component of STEM

Science (S)Science: aims to deal with the natural world and seek to understand it through knowledge Scientific. (National Governors Association (NGA),2010, 13)

Technology (T) Technology: aims to use, perceive, evaluate, and configure technology. The skills necessary to analyze the impact of technology on the individual and society.

Engineering (E) Engineering): aims to apply knowledge and mathematical and natural sciences acquired through study, experience, and practice, in a wise application. To develop ways to utilize these materials

And the factors of nature economically for the benefit of humanity, through engineering designs to solve real-life problems.

Mathematics (M): aims to develop students' ability to analyze and perceive ideas effectively, by teaching a broad base of mathematics basics and solving mathematical problems.

Education using the science, technology, engineering, and mathematics (STEM) approach is one of the important and promising global approaches in preparing and building school curricula, and it has been adopted over the past three decades when applied in several countries such as the United Kingdom, the United States of America, South Korea, and South Africa. (Straw. 2014.8)

Objectives of the STEM Approach:

According to William & Dugger (2013, 9), and affirmed by PCAST (2010, 15-16) and the National Research Council (2011, 4-5), STEM aims to achieve the following aims:

1. Enhancing students' academic achievement and performance, and advocating for educational reforms, especially considering international test results.
2. Providing opportunities to develop STEM practices essential across all professions in the 21st century.
3. Encouraging students to explore, inquire, and understand their world.
4. Boosting students' motivation and confidence in mathematics and sciences using technology, innovation, and design, enriching school experiences with engaging and meaningful experiments.
5. Cultivating students' thinking patterns such as scientific, critical, creative, and spatial thinking.
6. Increasing the number of students aspiring for advanced degrees and careers in STEM fields.

7. Expanding the qualified workforce in accordance with the STEM approach.
8. Equipping students with integrated scientific concepts along with their technological applications.
9. Developing students' research skills, problem-solving abilities, and decision-making skills.

Design Thinking

The concept of design that includes purposive orientations such as problem-solving, improvement of current conditions, or generating new ideas (Friedman, 2003) . Design thinking (DT) is a newer concept than the learning theories previously described; however, it does combine the elements and thought processes from philosophical, psychological, and Progressive learning theorists. The difference is that DT is not a learning theory but an instructional philosophy and methodology. The concept of design thinking (DT), developed based on the concept of design, is a human-oriented innovation approach that employs technological design tools to meet the requirements of individuals or businesses (IDEO, 2019).

Pavie & Carthy (2015) illustrates the impact of Design Thinking on the transformation of goods, services, processes, and strategy. Sheer, Swarts, & Ghadiali (2012) found that design educators that used Design Thinking in their classrooms were able to develop innovation, creativity, problem-solving skills, and strong teamwork among their students. Empathy, define, ideation, prototype, and test are the five primary phases that Design Thinking entails

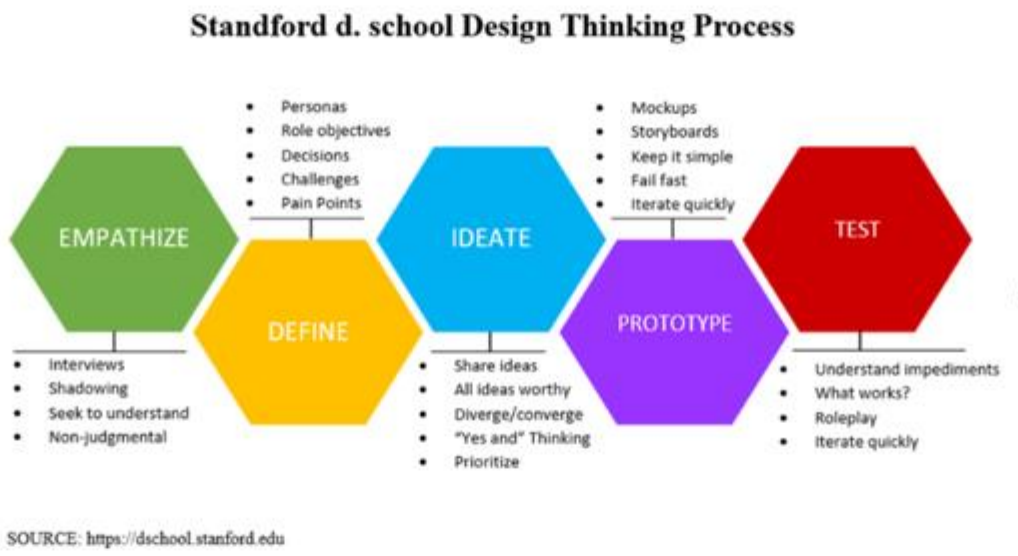
Öztürk (2020) reported that three DT approaches were mostly adopted in education literature:

1. Stanford University school,
2. IDEO (Design Thinking for Educators), and
3. HPI (Hasso Plattner Institute) design-centered thinking approach.

In the present study, the DT approach included 5 stages based on Stanford University (2009) description:

1. Empathy: Building empathy with people for whom you are designing and to understand what is crucial for them, how they interact with their environment
2. Define: Synthesizing the collected data into needs and insights to define problem statement: point of view
3. Ideate: Generating multiple ideas
4. Prototype: Turning ideas into physical forms by making prototypes
5. Test: Getting feedback from the users about the solution and developing them to reach better solutions

Figure (2) DT process(https://dschool.stanford.edu)



Students' Learning through (Engineering) Design in STEM Education

In school education, existing studies have shown that students can learn through design and develop their design thinking in and through STEM education. Specifically, with the recent

introduction of engineering into school education, there is a fast-growing set of programs and studies that document how engineering design can help engage students and facilitate their learning of STEM content. (English and King 2015; Kelley and Sung 2017; Kelly and Cunningham 2019; McFadden and Roehrig 2019). It presents an important topic area for us to further identify, examine, and compare specific epistemic practices pertinent to different disciplines in STEM that can possibly be connected or integrated to facilitate students' content learning and thinking development. Moreover, as STEM education is not culturally neutral (Early Childhood STEM Working Group 2017), Rather than focusing on the use of engineering design, some researchers and educators tried to develop and use design as a general pedagogical approach to engage students and help them learn in STEM and STEAM (with art specifically included in STEM) (Chen and Lo 2019; Orona et al. 2017) The positive effects of design activities in STEM clearly require careful instructional designs with specific theoretical perspectives. Further efforts are needed to explore both specific mechanisms and pedagogical constructs for developing and using design activity to facilitate students' content learning and thinking development. ((Li et al. 2019)
The previous literature proves that there are several literature analyses in design thinking in mathematics education but more focus on creative thinking and mathematical thinking like study KÖROĞLU & YILDIZ (2021) This aimed to investigate the experiences of pre-service teachers with the Design Thinking (DT) approach in mathematics education. The case study method, as a qualitative research approach, was employed in the study, and the Minecraft game was integrated into the DT process and presented to the pre-service teachers with a problem. The findings demonstrated that pre-service teachers should employ the DT approach in mathematics education, and that

mathematical process skills such as communication, reasoning, and proof, as well as mathematical concepts such as area, ratio-proportion, and pattern, were included in the DT approach with Minecraft. Man at el., (2022) This study also aimed to identify Design Thinking in Mathematics Education for Primary School , the findings indicated that the predominant authors developing design thinking were in Germany, Australia, USA, Singapore, and Switzerland, with fewer studies in other countries. Design thinking should be practiced by teachers in all subjects, as it is essential for students, especially in primary school, to ensure progress in the era of globalization. Painter (2018) This aimed to Using Design Thinking in Mathematics for Middle School Students. The findings indicated that most of the teachers did perceive that using Design thinking did help students master mathematical standards (Li at el., (2019) Design and design thinking are vital to creativity and innovation and have become increasingly important in the current movement of developing and implementing integrated STEM education. In this editorial, we build on existing research on design and design thinking and discuss how students' learning, and design thinking can be developed through design activities in not only engineering and technology, but also other disciplines as well as integrated STEM education.

Competence strategy

Strategic competence is one of the strands of mathematical proficiency. This strand includes problem solving and problem formulation, which require solving a problem by representing it mathematically: numerically, mentally, symbolically, verbally, or graphically. The key attribute for people who have achieved strategic competence is flexibility in their problem-solving processes and strategies. (suh et al., 2014)

As Groves (2012) pointed out, strategic competence is the ability of the learner to formulate and reformulate the problem mathematically and to devise strategies for solving it by relying on appropriate concepts and procedures. Problem-solving is essential for learning mathematics and means accepting the challenge of tackling a non-routine task without a clear solution. Rahayu, D. V. (2017) sees strategic competence as a mental activity in employing strategies to formulate, represent, and solve problem situations. Zubainur & Saminan (2019) defines Strategic competence as the ability to formulate, present, and solve math problems.

For this research, Strategic competence is the ability to use effective strategies to formulate and solve problems. In the practical experiments of mechanics, this competence enhances students' understanding and develops their skills in applying mechanical theories to real-world situations, helping them solve problems in innovative ways.

MacGregor (2013) confirmed that strategic competence can be developed in learners through the repeated presentation of mathematical problems that reflect real-world situations. This allows them to distinguish between necessary data and identify relevant information in the problem, as well as unrelated information, and to determine specific methods for solving and generating diverse ideas and solutions. Learners who lack strategic competence are unable to approach mathematical problems and do not know the appropriate strategies to solve them. There are reciprocal relationships between strategic competence and both conceptual understanding and procedural fluency. Building strategies for solving unfamiliar problems heavily relies on understanding the relationships and information involved, and fluency helps in selecting the most appropriate procedures to solve these problems. (MacGregor ,2013)

Indicators of strategic competence in learners include the following: (Lesh et. al 2003; Suh et al. 2012; NCR,2001)

1. Formulates and represents mathematical problems.

2. Relies on known formulas to solve problems.
3. Identifies necessary data and ignores irrelevant information.
4. Verifies reaching a specific case that helps as an entry point to solving the problem instead of the general case.
5. Generates models of the mathematical problem."

In addition, a teacher who has strategic competence can intentionally use representations such as student-created diagrams, graphs, manipulative models, and numeric or verbal statements as pedagogical content tools (Rasmussen and Marrongelle 2006)

Another mathematical competence that students need in solving mathematical problems is strategic competence. This competency helps students apply the right strategy to find solutions to a problem. Strategic competence requires students to monitor progress and develop alternative plans if the strategies used are predicted to be less effective. (Ostler,2011)

Students need to know various ways and strategies for problem solving. Students also need to know the right strategies to be applied in solving specific problems. After the students can formulate the problem, the next step is to represent it mathematically, either in numerical, symbolic, verbal, or graphical form. (Kilpatrick & Findell,2001)

Strategic competence allows students to formulate, present, and solve problems in a mathematical way. Adaptive and strategic competence is part of math proficiency. Math proficiency consists of conceptual understanding, procedural fluency, strategic competence, adaptive reasoning, and productive disposition. (Kilpatrick & Findell,2001)

From the above, it is clear that strategic competence has three main skills:((Khabibah & Widyanti, 2020)

1- The skill of formulating and composing a mathematical problem: which is converting a life problem into a mathematical formula or problem, explaining the meaning of the problem, rephrasing it in the learner's own words, forming a meaning for the problem, analyzing it to determine the data and what is required, and searching for information. Missing information and eliminating redundant information.

2- The skill of representing a mathematical problem, which is analyzing life situations and representing them using mathematical language, drawing, pictures, tables, simple equations, and graphs. And linking different representations and choosing the appropriate representation for the issue accurately.
3- The skill of solving a mathematical problem: It is a set of steps and procedures that the student takes using his previous experience of concepts and the skills he has acquired to find what is required. It comes after understanding the mathematical problem and knowing the relationships between its elements and determining what is required in it, then choosing the appropriate plan for the solution and implementing it, finding the solution and reviewing it. And check it.

Leite study (2019) aimed to determine whether strategic competence is enhanced using technology in mathematics classrooms. The study revealed that teachers recognize that students' problem-solving skills are enhanced by using technology, provided that appropriate devices, software, and infrastructure are available. Additionally, teachers need training and support to effectively apply technology for purposes such as problem-solving in mathematics classrooms.

Zubainur& Saminan study (2019) aimed to adaptive reasoning and strategic competence through problem-based learning model in middle school. The results show that students' adaptive reasoning ability can be initiated through learning by PBL model. Two out of the three strategic competence indicators are met by all students. The two indicators are understanding and presenting math problems to verbal forms and selecting the right formula, approach and/or method to solve the problem

Copur-Gencturk, & Doleck study(2021) aimed to demonstrate the various practices of strategic competence among teachers The results showed that teachers' strategic competence was closely linked to whether they devised a correct strategy and how they dealt with known and unknown quantities in solving verbal problems. The study also found that teachers with strong strategic competence frequently used algebraic symbols and mathematical representations and dealt with unknown quantities

Experimental procedures :

1- Experimental design for the research:

The research relied on the experimental method based on a quasi-experimental design Two groups (experimental, control) with two measurements (pre, post), one experimental group to be taught using the practical experimental and the other there controlled, taught in the traditional way, and the tools applied were design thinking test, Strategic Competence test pre on the two groups, the results were monitored and processed statistically to ensure the equality of the two groups, the unit “Analysis of Algebraic Expressions” was taught to the students in the first year of Dakahlia STEM school, first semester, after reformulating it. The experimental group used Practical Experiments for learning Mechanics Syllabus while the control group studied the same Mechanics Syllabus, by traditional method. The research tools post applied are design thinking test, and Strategic Competence test. The two research groups (experimental and control) and the results were monitored, processed, analyzed and interpreted Results

2-Research two groups:

The two research groups (experimental and control) were selected from first year of secondary school students in Dakahlia STEM school, first semester 2023/2024, after ensuring that the ages mean of the students are similar, and the social, economic level of the students is similar. The chronological age of each student was obtained based on the academic records of the STEM school. Mann- Whitney- test was used to calculate significance Statistics for the difference between the average ages of students in the experimental and control groups after Converting annual ages to their monthly equivalents(Salih Murad 2000, 273.) After controlling the variables related that may affect the research results, the number of students in the two research groups were (40) students divided into (21) students, as an experimental group and (19) as a control group.

3-Research materials and tools:

List of Design thinking skills:

To answer the first question of the research, which states: "What are Design thinking skills that can be developed among the students of the first year STEM school?. The researcher prepares a list of Design thinking skills according to the following steps:

1. List goal:

- The list aimed to identify Design thinking skills appropriate for first year STEM student school.

2. Initial list of Design thinking skills:

After reviewing mechanics syllabus, studies and research that dealt with design thinking developing a preliminary vision for a list of design thinking skills, consisted of (5) skills.

List of conceptual comprehension skills:

The list was presented to a number of (9) juries, to ensure its integrity Linguistic and scientific formulation, as well as the suitability of these skills for first year STEM student school. The most important recommendations of the juris were the deletion of some performance indicators because they were not suitable for students in the first year STEM student school, as well as modifying some of the linguistic formulations of the performance indicators. After making the modifications recommended by the juries, the conceptual comprehension skills necessary for Dakahlia STEM school students have become in its final form.

Design thinking test:

1. Purpose of the test

The test aims to measure the level of ability of first year Dakahlia STEM student school in the “mechanics syllabus” of Design thinking skills.

2- Dimensions of the test

The dimensions of the Design thinking test were determined considering special performance indicators with Design thinking skills

3-Test vocabulary in its initial form:

After determining the performance indicators Design thinking skills, the Design thinking test was developed in its initial form, and the Design thinking test was formulated. essay questions and production-answer questions.

4-Test instructions

The test instructions included the following: clarifying the purpose of the test, not leaving a question unanswered, reading the questions carefully to make it easier for you to answer, and writing the solution steps in the case of questions. In the article, write the basic data, which is the name and date Class, and school.

5-Test setting

The test was presented in its initial form to (9) juries specialized in the field of teaching and learning mathematics, to ensure the suitability of the test for application by expressing their opinion on the test vocabulary and the suitability of this vocabulary for Design thinking skills, and the suitability of the Design thinking test for first year Dakahlia STEM students' school. As well as expressing their opinion on the test instructions and their degree of clarity and safety Its verbal formulation.

6.Exploratory testing **:**

The test was applied to a sample of (18) students from the first year Sharqia STEM students' school to ensure that test instructions are clear. The clarity of the instructions for the Design thinking test was confirmed after the judge's made adjustments, which consisted of making some verbal adjustments to some words to suit the students of the first year of Dakahlia STEM school and to suit the nature of the test, and then writing instructions.

Test validity:

1. The apparent validity of the test:

The test was implemented honestly by presenting it to a number of (9) distinguished arbitrators in the field of curricula and methods of teaching mathematics, and their amendments consisted of deleting some vocabulary that was not appropriate for the dimension at the end of the work or that it was not appropriate for his students. first year of STEM school

2. Internal consistency validity of the test:

The researcher used the internal consistency coefficient by calculating the correlation coefficient between the scores Each item and the dimension to which it belongs, and the following table explains this:

Table (1) Correlation coefficients between each test item and the total score

Skills	Questions	Correlation coefficient
Empathy	Q1	0.531
	Q2	0.794
	Q3	0.858
	Q4	0.680
	Q5	0.778
	Q6	0.849
Ideate	Q1	0.668
	Q2	0.534
	Q3	0.564
	Q4	0.682
	Q5	0.521
	Q6	0.627
Defined	Q1	0.915
	Q2	0.762
	Q3	0.722
	Q4	0.905
Prototype	Q1	0.656
	Q2	0.529
	Q3	0.613
	Q4	0.625
	Q5	0.602
	Q6	0.523
Test	Q1	0.846
	Q2	0.636
	Q3	0.626
	Q4	0.527
	Q5	0.846
	Q6	0.582

The previous values of the correlation coefficients indicate that the test has an appropriate degree of Validity in measuring design thinking skills.

Table (2): Correlation coefficients between the total score of each dimension and the overall score of the design thinking

No	Main skill areas	Correlation coefficient
1	Empathy	0.888
2	Defined	0.763
3	Ideate	0.909
4	Prototype	0.732
5	Test	0.901

The previous values of the correlation coefficients indicate that the test has an appropriate degree of Validity in measuring design thinking skills.

Reliability of the test:

Cronbach's Alpha was used to calculate the reliability coefficient of the test through excluding the item score from the total score of the test. The calculated reliability coefficient was 0.75, which verifies the Reliability of the test. Table 3 shows Cronbach's alpha coefficient of every domain.

Table (3) Cronbach's Alpha Coefficient values of the design thinking test

Main skill areas	Number of Items	Cronbach's alpha
Empathy	6	0.71
Defined	4	0.66
Ideate	6	0.80
Prototype	6	0.72
Test	6	0.77
Total	28	0.75

Table (3) shows Alpha reliability coefficients for the domains and the whole test of design thinking. The coefficients for the skills are 0.71, 0.66, 0.80, 0.72,0.77in sequence. Moreover, the reliability coefficient is 0.75 for the whole test which is a high reliability ratio. Therefore, the test is reliable to be applied.

Testing time:

The time taken by each individual student to answer the test questions was monitored, and then the average of these times was calculated(Saeed Muhammad ,2009, 284). The time taken to complete the test was approximately (90) minutes.

Difficulty coefficients:

The ease coefficients for the items in the mathematical proficiency test fell in the period [0.27, 0.74] and the difficulty coefficients for the test items fell in the period [0.26, 0.73]. Thus, all test items become appropriate in terms of ease and difficulty

Discrimination coefficients

The discrimination coefficients of the test items were calculated using the terminal differences method, and the discrimination coefficients of the test items fell in the period [0.34, 0.77], thus becoming All test items are appropriate in terms of discrimination

Final form of the test:

After statistical control of the test, the test was prepared in its final form, The test in its final form consists of a cover page containing the name of the test and test instructions, which students are asked to read carefully before starting to answer the test questions and record their data on this page, then the parts of the test. It consists of (28) question.

Answers correction:

2 points for each correct answer . The maximum test score reached (56) points. A rating scale for the vocabulary of the design thinking test was prepared to facilitate correction.

Competence strategy test:

1**.** Purpose of the test:

The test aims to measure the level of ability of first year Dakahlia STEM student school in the "mechanics syllabus" of competence strategy indicators.

2- Test dimensions:

The dimensions of the competence strategy test were determined considering special performance indicators with competence strategy skills

3- Test vocabulary:

After determining the performance indicators competence strategy skills, the competence strategy test was developed in its initial form, and the competence strategy test was formulated. essay questions and production-answer questions.

4-Test instructions

The test instructions included the following: clarifying the purpose of the test, not leaving a question unanswered, reading the questions carefully to make it easier for you to answer, and writing the solution steps in the case of questions. In the article, write the basic data, which is the name and date Class, and school.

5-Test setting

The test was presented in its initial form to a number of (9) arbitrators in the field of teaching and learning mathematics, in order to ensure the suitability of the test for application by expressing their opinion on the test vocabulary and the suitability of this vocabulary for competence strategy skills, and the suitability of the competence strategy test for first year Dakahlia STEM students' school. As well as expressing their opinion on the test instructions and their degree of clarity and safety Its verbal formulation.

6. Test Exploratory study:

The test was applied to a sample of (18) students from the first year Sharqia STEM students' school .

Test instructions:

The clarity of the instructions for the competence strategy test was confirmed after the judge's made adjustments, which consisted of making some verbal adjustments to some words to suit the students of the first year of Dakahlia STEM school and to suit the nature of the test, and then writing instructions. The test is in its final form.

Test validity:

1. The apparent validity:

The test was implemented honestly by presenting it to a number of (9) distinguished arbitrators in the field of curricula and methods of teaching mathematics, and their amendments consisted of deleting some vocabulary that was not appropriate for the dimension at the end of the work or that it was not appropriate for his students. first year of STEM school

2. Internal consistency validity:

The researcher used the internal consistency coefficient by calculating the correlation coefficient between the total score of each Dimension and the overall score of the competence strategy, and the following table explains this:

Table (4): Correlation coefficients between the total score of each Dimension and the overall score of the competence strategy

No	Main indicators areas	Correlation coefficient
1	Formulates a mathematical problem based on a set of data	0.887
2	Represents mathematical problems with a diagram or chart	0.831
3	Solves mathematical problems in multiple ways	0.776
4	Creates a similar mathematical problem to a given one	0.566
5	It identifies the important givens in the problem and ignore the excess givens	0.857
6	Proposes alternative solutions to incorrect solutions	0.729

The previous values of the correlation coefficients indicate that the test has an appropriate degree of Validity in measuring competence strategy Indicators.

Reliability of the test:

Cronbach's Alpha was used to calculate the reliability coefficient of the test through excluding the item score from the total score of the test. The calculated reliability coefficient was 0.75, which verifies the Reliability of the test. Table 3 shows Cronbach's alpha coefficient of every domain.

Table (5) Cronbach's Alpha Coefficient values of the design thinking test

Main indicators areas	Cronbach's alpha
Formulates a mathematical problem based on a set of data	0.78
Represents mathematical problems with a diagram or chart	0.85
Solves mathematical problems in multiple ways	0.89
Creates a similar mathematical problem to a given one	0.72
It identifies the important givens in the problem and ignore the excess givens	0.79
Proposes alternative solutions to incorrect solutions	0.89
Total	0.79

Table 5 shows Alpha reliability coefficients for the domains and the whole test of design thinking. The coefficients for the skills are 0.78, 0.85, 0.89, 0.72,0.79,89 in sequence. Moreover, the reliability coefficient is 0.79 for the whole test which is a high reliability ratio. Therefore, the test is reliable to be applied.

Testing time:.

The time taken by each individual student to answer the test questions was monitored, and then the average of these times was calculated. Saeed Muhammad (2009, 284). The time taken to complete the test was approximately (60) minutes.

Difficulty coefficients:

The ease coefficients for the items in the mathematical proficiency test fell in the period [0.28, 0.72] and the difficulty coefficients for the test items fell in the period [0.28, 0.72]. Thus, all test items become appropriate in terms of ease and difficulty

Discrimination coefficients:

The discrimination coefficients of the test items were calculated using the terminal differences method, and the discrimination coefficients of the test items fell in the period [0.38, 0.75], thus becoming All test items are appropriate in terms of discrimination

Final form:

After statistical control of the test, the test was prepared in its final form, The test in its final form consists of a cover page containing the name of the test and test instructions, which students are asked to read carefully before starting to answer the test questions and record their data on this page, then the parts of the test. It consists of (12) questions.

Answers correction

2 points for each question producing an answer. The maximum test score reached (24) points. A rating scale for the vocabulary of the competence strategy test was prepared to facilitate correction.

Results and interpretation:

After the post-application of the research tools: design thinking test and strategic competency test on the experimental and control research groups, the student's answers were corrected, and the scores of each group were monitored and recorded separately, then statistically processed using appropriate statistical methods by SPSS program ver. 23

First hypothesis:

which states that there is a statistically significant difference when. (α) > 0.05) level Between the average ranks of the scores of the students of the experimental and control groups in the post-application of the design thinking test in favor of the students of the experimental group, the Mann-Whitney test was used, and the results were as in the following table:

Table (6): Results of the Mann-Whitney test for the significance of the differences between the means of the ranks Scores of the experimental and control groups in the post-application of the design thinking test.

Variable	Study groups	No	Mean rank	Sum ranks	U	W	Z	P - value
Design thinking test	Experimental group	21	30	630	7.21	190	-5.41	significant
	Control group	19	10	190				

the previous table show that there is a statistically significant difference at the level of α≤0.05 between the average scores of the students of the experimental and control groups in the post-application of the design thinking test in favor of the students of the experimental group, as the average of experimental group's ranks are greater than the average ranks of the control group, and this confirms that The validity of the first hypothesis. This statistically significant difference can be explained by the teaching of the topics of the mechanics syllabus, which were reformulated according to the practical experimental for the experimental group, while the same topics were taught to the control group, but from the traditional method, and this is due to what the mechanics syllabus includes. After reformulating it into activities and exercises, it provided the opportunity for the students to refer to their previous knowledge and experiences to make predictions in the light of this knowledge and experiences, as well as to link ancient ideas with modern ones, which works to develop their design thinking, and this result is consistent with KÖROĞLU & YILDIZ (2021), Man at el., (2022), Painter (2018), Li at el., (2019), With the results of each study.

Second hypothesis:

which states that there is a statistically significant difference when. ($\alpha > 0.05$) level Between the average ranks of the scores of the students of the experimental and control groups in the post-application of the competence strategy test in favor of the students of the experimental group, a test was used. Mann-Whitney, and the results were as follows:

Table (7): Results of the Mann-Whitney test for the significance of the differences between the means of the ranks the scores of the two research groups in the post-application of the competence strategy test.

Variable	Study groups	No	Mean rank	Sum ranks	U	W	Z	P - value
Design thinking scale	Experimental group	21	30	630	6.21	190.00	-5.435	significant
	Control group	19	10	190				

the previous table show that there is a statistically significant difference at the level of $\alpha \leq 0.05$ between the average scores of the students of the experimental and control groups in the post-application of the competence strategy test in favor of the students of the experimental group, as the average of experimental group's ranks are greater than the average ranks of the control group, and this confirms that The validity of the third hypothesis. This statistically significant difference can be explained by the teaching of the topics of the mechanics syllabus, which were reformulated according to the practical experimental for the experimental group, while the same topics were taught to the control group, but from the traditional method, and this is due to what the mechanics syllabus includes. After reformulating it into activities and exercises, it provided the opportunity for the students to refer to their Formulates a mathematical problem based on a set of data and represents mathematical problems with a diagram or chart and Solves mathematical problems in multiple ways and Creates a similar mathematical problem to a given one as well as Proposes alternative solutions to incorrect solutions, which works to develop their competence strategy, and this result is consistent with Leite (2019), Zubainur& Saminan (2019), Zubainur& Saminan (2019), Copur-Gencturk, & Doleck, (2021), With the results of each study.

Effectiveness of results:

The mechanics syllabus using practical experiments in developing design thinking among the students of the experimental group, the Blake equation was used to calculate the adjusted gain percentage, and the following table shows the results that were reached.to her.

Table (8): Blake's adjusted gain percentage for the effectiveness of using practical experiments in developing design thinking scale among students in the experimental group

Dimension of scale	Application	Mean	Maximum	Bleke	Effectiveness
Design thinking	Pre- test	42.476	94	1.3	Biggest
	Post-test	85.095			

The previous table shows that the effectiveness of teaching the mechanics course was to a large degree in developing the dimensions of design thinking for me Secondary school STEM students This result can be explained by the positive impact of teaching using practical experiments and the steps they include that provide students with the opportunity to train in design thinking skills. Refer to their Building empathy with people for whom you are designing and synthesizing the collected data into needs and insights to define problem and generating multiple ideas and Turning ideas into physical forms by making prototypes as well as Getting feedback from the users about the solution and developing them to reach better solutions, which works to develop their design thinking.

Table (9): Blake's adjusted gain percentage for the effectiveness of using practical experiments in developing competence strategy among students in the experimental group

Dimension of test	Application	Mean	maximum	Bleke	Effectiveness
competence strategy	Pre- test	12.578	24	1.2	biggest
	Post-test	21.381			

The previous table shows that the effectiveness of teaching the mechanics course was to a large degree in developing the dimensions of competence strategy for me Secondary STEM school students This result can be explained by the positive impact of teaching using practical experiments and the steps they include that provide students with the opportunity to train in competence strategy skills. Refer to their Formulates a mathematical problem based on a set of data and represents mathematical problems with a diagram or chart and solves mathematical problems in multiple ways and creates a similar mathematical problem to a given one as well as Proposes alternative solutions to incorrect solutions

Recommendations:

1. Employ practical experiments comprehensively within the mechanics curriculum to enhance practical and applied understanding.
2. Systematically integrate design thinking skills into mechanics lessons to enhance problem-solving abilities and creative solution design.

3. Adopt continuous assessment methods to measure the development of strategic competence in various aspects of mechanics.
4. Establish partnerships between STEM schools and scientific and industrial institutions to enhance practical experiments and connect theoretical education with real-world applications.

Suggestions:

1. Study of the effectiveness of using practical experiments in the mechanics syllabus in developing athletic prowess
2. Studying the effectiveness of using practical experiments in different grades and stages of study.
3. Preparing a program to train student teachers in the mathematics department on using practical experiments in the mechanics' syllabus
4. Studying the use of different strategies and models in developing students' strategic competency and design thinking skills.

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