The Effectiveness of STEM Approach on Development of Decision Making and Metacognitive Thinking

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Abstracts

The aim of this study is to explore the effect of STEM-based learning on metacognitive thinking and identify the relationship between metacognitive thinking and decision-making in a sample of public-school students in Palestine. The quasi-experimental design and the descriptive correlational design were used. The study's results indicate statistically significant differences and in favor of the post-application of the decision-making scale, which point to the positive effect of the applied program. The most important recommendations is to conduct studies on the effectiveness of the STEM approach on the development of other types of thinking, such as logical, geometric, and creative thinking.

Keywords: STEM, Decision making, Metacognitive, Thinking.

Introduction

The accelerated scientific and technical developments and the knowledge explosion are some of the most prominent features of this era that we are living in which contribute effectively and influentially in all fields, especially the educational field, which has made the world a small village. Traditional teaching methods such as lecturing, indoctrination, and memorization are no longer able to keep pace with these developments, in addition to their inability to create a generation of learners capable of finding creative ideas and applying them in daily life.

In the twenty-first century, the trend has increased toward the employment of school learning in various areas of life, the use of technology, the development of self-learning, and reliance on learning based on modern educational theories. Many studies have recommended the necessity of avoiding indoctrination and memorizing unrelated facts, which loses its functional character and full understanding of it. In addition to the scarcity of integrated educational situations through which the student can be trained in the skills of this century, the most important of which are decision-making skills (Othman, 2008; Al-Tamimi, 2013; Tarawneh, 2006).

The decision-making process has gained the importance of researchers, educators, and psychologists, they are keen to understand it scientifically and explain it. They proposed many models, plans, and programs to improve the students' decision-making process, despite their differences in scientific, educational, and psychological trends and schools. The researchers agreed that the decision-making process has become an essential process in the individual's life, enabling him to choose the most appropriate alternative from a group of alternatives to solve his daily problems and help him adapt to the conditions of the environment surrounding him. Also, the decision-making process is a critical part of his personal and professional life, and choosing a future profession requires the application of thought, information processing, and sufficient depth of thinking about these decisions.

Baiocci, Laghi & Dalessi (2009) believe that decision-making skill is considered one of the most important skills that should be strengthened and acquired by the individual due to its importance in life at all professional, personal, social and academic levels, as it includes many cognitive processes such as information processing, problem-solving, judgment, and working memory, and requires a certain amount of mental and emotional energy, starting with the design stage and ending with the decision-making and implementation stage,

The fact that decision-making process is a complex thinking process and controlling its course to reach an appropriate decision, it also requires higher control processes in thinking, planning, monitoring, and evaluating the decision, so it meets and intersects significantly with metacognitive thinking, which is considered one of the complex mental skills that constitute intelligent and directed behavior to process information and control all thinking activities working and directed to solve the issue effectively (Jarwan, 2002).

Learning theories seek to reduce the role of memorization and repetition and highlight the role of understanding through the use of strategies that make the individual active, searching for knowledge and learning, positive, and seeking to develop his information. Thinking is a process carried out by the brain in response to sensory input from our five senses. It involves invisible mental activities, with our observations and interactions being the tangible results of this cognitive process, expressed through writing, speech, movement, or visual representations. (Kazim, 2009).

By reviewing previous studies and research, the researchers noticed that metacognitive thinking has received great attention because of its importance in improving the way of thinking and working to provide the learner with awareness of what he is learning. The learner who practices metacognitive thinking follows regular steps in solving a specific problem and performs several simultaneous roles. He is a generator of ideas, a planner, a critic, a monitor of the progress of his thinking process, and a guide to it. He puts in front of him several alternatives to solve the problem and compares them to choose the most appropriate one, thus becoming a productive thinker.

The researchers also believe that the student's mastery of decision-making skills and metacognitive thinking skills enables him to reach higher levels of thinking to keep pace with technological and cognitive developments, and provides an organized framework that ensures their involvement in the learning process and helps them build their self-confidence, thus, it

constitutes an effective contribution to preparing them to face the future and participate effectively in civil, professional and academic life.

The STEM approach is a systematic educational reform movement that relies on the integration and combination of Science, Technology, Engineering, and Mathematics disciplines to improve students' abilities to solve problems and creativity to prepare an educated and proficient generation of these components, capable of solving problems comprehensively and with a positive perspective to raise economic competitiveness (Hilal, 2021).

The STEM approach aims to find innovative solutions to real-life problems and create a generation of scientists, technicians, and engineers by working to apply the knowledge and skills acquired from the group of disciplines that make up STEM in an integrated manner. It also develops students' abilities to think critically and creatively and make decisions, which shows us the harmony between the skills sought from the application of the STEM approach and the skills of the 21st century which confirms the idea of the current research by using the STEM approach to develop decision-making skills and metacognitive thinking skills.

The STEM approach focuses on activities and projects in education, giving students opportunities to participate in defining the problem and making appropriate decisions to solve it, this makes the educational process more attractive to students, as it encourages them to learn through various thinking skills, including metacognitive thinking, based on constructivist theory as an alternative to traditional education that is based on indoctrination, memorization, and repetition, which makes students feel bored (Barak, 2014).

STEM-based learning relies on applied activities that employ scientific, mathematical, and engineering knowledge through technology activities and digital software by presenting questions and issues whose solution requires the use of scientific thinking activities and higher-order thinking skills, including metacognitive thinking, which makes the attention focus of the educational process is the learner (Al-Mohammadi, 2018).

The researchers see great importance in linking decision-making skills with metacognitive thinking skills and training students in them through STEM-based learning, and from here the problem of the current study became clear.

Study problem

Education in light of the STEM approach is crucial in the learning process due to it provides educational strategies and methods that are compatible with the requirements of the twenty-first century, such as thinking of all kinds and teamwork. After all, it is based on the process of merging and integrating the fields of Science, Technology, Engineering, and Mathematics, as well as because of its effect on the improvement the teacher's skills in raising a challenge among students and stimulating their thinking and solving problems (Aboushi & Shana'a, 2022; Al-Farhan, 2018; Bybee, 2013; Lou, et al, 2016; Marsha, 2006).

Based on the above, and in response to the calls for educational reform, and to the aspirations of the Palestinian Ministry of Education to adopt the STEM approach in teaching Science, Technology, Engineering, and Mathematics at the elementary stage, this research came to highlight the skill of decision-making and metacognitive thinking as modern concepts that have

received wide attention from educators and researchers. In light of the scarcity of studies that have examined the effect of the STEM approach on metacognitive thinking and decision-making, the problem of the study revolved around answering the main question:

What is the effectiveness of STEM-based learning in the development of decision-making and what is its relationship to metacognitive thinking among elementary stage students?

Study questions:

The following sub-questions emerge from the main study question:

- Are there statistically significant differences at the ($\alpha \leq 0.05$) level between the average scores of students in the pre-and post-applications of the decision-making scale?
- Are there statistically significant differences at the ($\alpha \leq 0.05$) level between the average scores of students in the pre-and post-applications of the metacognitive thinking scale?
- Are there statistically significant differences at the ($\alpha \leq 0.05$) level between the averages of the research group's response to the post-application of the decision-making and metacognitive thinking scale due to the gender variable?
- Are there statistically significant differences at the ($\alpha \leq 0.05$) level between the averages of the research group's response to the post-application of the decision-making and metacognitive thinking scale due to the variable of place of residence?
- Is there a statistically significant relationship at the ($\alpha \leq 0.05$) level between the average scores of students who studied according to the STEM methodology in the post-application of the two scales of decision-making skill and metacognitive thinking skill?
- Study importance

The importance of the current work is obvious in both theoretical and applied fields:

- Theoretical field: Providing integrated information about the STEM approach and how to use it in the learning process at school, in addition to drawing the attention of school curriculum developers and makers to the importance of enriching the curriculum and enhancing it with units according to the STEM approach to develop twenty-first-century skills, especially decision-making skills, and metacognitive thinking skills.
- Applied field: Enriching the research aspect and directing the attention of researchers in Palestinian universities to the STEM approach for further research and studies. In addition to revealing the effect of teaching according to the STEM approach on the development of decision-making skills and metacognitive thinking skills, and emphasizing the student's centrality to the educational process, its fruitfulness, and the purpose of its existence, the research also provides research instruments to measure the skills of decision-making and metacognitive thinking.

Study aims

The study aims are as follows:

- Knowing the effect of a training program designed according to the STEM approach on the development the skills of decision-making and metacognitive thinking skills among students in the seventh, eighth, and ninth grades.

- Studying the differences between the average responses of the group that studied according to the STEM approach in the skills of decision-making and metacognitive thinking on the pre-and post-study instruments.

Study limits:

The limits of the current research are as follows:

- Thematic limits: developing some contemporary century skills (decision-making and metacognitive thinking), as the focus of decision-making was limited to skills (diagnosing the problem, generating alternatives, evaluating alternatives, making the appropriate decision), while the scale of metacognitive thinking was limited to skills (planning, monitoring and control, and evaluation).
- Human limits: This research was carried out on a sample of school students (randomly selected) by the Tulkarm Education Directorate and the Qalqilya Education Directorate, numbering (59) students (male and female) from the upper elementary stage.
- Spatial limits: The experience of teaching (Science, Technology, Engineering, and Mathematics) according to the (STEM) approach was implemented in the halls, laboratories, and workshops of Palestine Technical University-Kadoorie, and a training program was implemented that included activities according to the STEM approach.
- Temporal limits: This study was applied in the summer semester (summer vacation) of 2020/2021.

Theoretical Framework

Metacognitive Thinking

The concept of metacognition is a modern concept that appeared in the seventies of the last century, where one of the first to use the concept was the scientist John Flavell, and it developed later as the opinions of scholars differed in its definition. Flavell (1992) defined it as the individual's ability to control his thinking processes through various strategies, such as regulation, monitoring, and adaptation. It is also an individual's ability to think about the tasks or processes he undertakes and to choose and use appropriate strategies needed in his intercultural interactions. Swartz defined it as an individual's awareness of his mental strengths and weaknesses, control over his mind, and attention to his thinking processes before, during, and after a specific action (Dwyer, 2008:14).

Mariano et al. (2021) highlighted that students frequently focus on memorizing information for exams rather than developing a deeper understanding of the curriculum. This approach often leads to a superficial grasp of the material. The authors emphasized the importance of metacognitive strategies in helping students become effective learners. They also underscored the potential of using these strategies in STEM education to enhance student engagement and improve learning outcomes.

Decision Making:

Decision-making skills are among the skills of the twenty-first century that aim to improve education. Decision-making can be defined as selecting a choice from among many other options

and alternatives. Additionally, choosing the optimal alternative that achieves the desired goal and is supported by argument and proof, decision-making is a process and not an immediate process but rather requires skills and steps to take (Altan et al, 2018).

Decision-making skills are a selection process that be subject to mental function. It is a mental, cognitive process limited to a sequence of mental activities, such as attention, perception, initiative, and achievement to realize the desired goal after identifying and choosing the optimal alternative (Al-Taie, 2001). Also, the ability to make decisions is considered a desirable goal to be achieved in the educational system, by preparing students who are able to choose the best alternative to confront and solve the problem (Al-Hamdani, 1982).

Ricky (1993: 202) defined decision-making as "the process of choosing the appropriate alternative from among multiple alternatives, based on the decision maker's belief that his decision is necessary." Jarwan (2010, 105) also defined it as a complex process that seeks to choose the best alternative or the appropriate solution available to the decision-maker in diverse and different life situations, to reach the desired goal.

Study terminology

Metacognitive: Defined by Flavell (1976) as the ability to think about an individual's current cognitive processes.

As defined by Sternberg (1985), skills are based on highly controlled processes, the most important sub-elements of which are: planning, monitoring, and evaluation, and their function is to manage and direct various thinking processes to confront problems and solve them in a conscious and aware manner.

Procedural definition:

Decision-Making skill: Mousa (2010:30) defined it as a process in which research and comparison are made between a number of available alternatives and options, then choosing the best alternative in achieving the desired goals. This process is followed by the decision maker at an effective level by investing in the available environmental capabilities.

Sing defined it as a process during which an alternative is chosen from among several alternatives in a particular situation (Sing, 2000: 17).

Procedural definition: The ability to choose the optimal and best alternative, rationally, with the aim of determining the necessary procedures to solve the problem and achieve the desired goals.

Previous Studies:

Abu Thantain (2021) study aimed to reveal the effect of employing the STEM approach in teaching science to develop decision-making skills among gifted pupils in the intermediate stage in Afif Governorate in Saudi Arabia. The quasi-experimental design was applied with (one group: pre- and post-test) design. The study sample consisted of (18) gifted students, the researcher applied the decision-making skills scale to the study sample. The study results displayed that there were statistically significant differences between the average of the experimental group scores in the pre-and post-application on the total score, and on each skill of

the basic skills scores for measuring the decision-making skills, which identified as ten basic skills, and were in favor of the post-application, the results also displayed a significant effect of using the STEM approach in teaching science and improving decision-making skills among gifted students.

Wahono et al. (2021) conducted a study to investigate how students' worldviews influence decision-making. The study focused on an Indonesian case and used a pre-experimental design with two groups of junior high students. The sample included 109 students (male and female). The findings revealed distinct patterns in students' initial decisions based on their worldview. Additionally, the study discussed the practical implications of using socio-scientific issue-based instruction through integrated STEM education, highlighting the important role of teachers in complex lesson topics. Overall, the study emphasized the importance of implementing these programs.

Akaydın et al. (2020) study aimed to identify the relationship of metacognitive awareness to skills of decision-making in third and fourth-grade students in Marmaris Province, Turkey. The sample contained (143) students (male and female), and the descriptive correlational approach was used. They found in their results the level of metacognitive thinking and students' awareness of decision-making skills was high, it also showed that there is a weak positive relationship between metacognitive awareness and awareness of decision-making skills among the study sample. They also did not find any differences in metacognitive awareness and awareness of skills of decision-making according to the variables of gender and grade level. The study findings indicated that important for teachers to involve students in activities to develop their metacognitive awareness, which can also develop their decision-making skills.

In Essam's (2021) study seeks to determine the relationship between metacognitive thinking and decision-making in executing offensive technical-tactical actions among football students at the National High School of Sports. The sample involved 21 National School of Secondary Sports - Sahal Ibrahim supplement students in Oum El Bouaghi, Algeria. The findings indicated a positive correlation between metacognitive thinking and decision-making in executing offensive technical-tactical actions among football students at the sports high school.

Nasr (2019) conducted a study at Damascus University involving 300 students from the faculties of Law and Education (Department of Psychology). The study aimed to explore the connection between metacognitive thinking skills and decision-making abilities. The results indicated a statistically significant relationship between metacognitive thinking and decision-making among the participants. Additionally, there were no significant differences in metacognitive thinking scores based on gender. In the research sample, gender was found to have a statistically significant impact on decision-making scores. However, there were no statistically significant differences in thinking and metacognitive scores based on specialization. On the other hand, specialization did show a statistically significant influence on decision-making capacity scores in the research sample.

Altan et al. (2018) conducted an in-depth study aimed at identifying the use of STEM-based learning to teach Science, Technology, Engineering, and Mathematics and its effectiveness in developing decision-making skills among pre-service science teachers. An integrated design

(quantitative and qualitative) was used in the quantitative dimension. The quasi-experimental approach was used in a one-group design, a pre-and post-test application. The test for decision-making skills was administered to 36 teachers (male and female). In the qualitative phase, a multiple-case design was utilized, involving semi-structured interviews with 6 teachers. The results showed a significant improvement in decision-making skills from pre-test to post-test. Additionally, the study identified key steps in the decision-making process related to real-life design challenges, including problem identification, evaluation of alternatives, decision application, and decision and application steps.

Mahfoud (2017) conducted a study that aimed to identify metacognitive thinking skills and their relationship to decision-making skills in public schools in the city of Damascus. The study sample consisted of (550) male and female students from the second secondary school and was selected using a cluster random method. The output of the study displayed that the overall score for metacognitive thinking skills is moderate, and the overall score for decision-making skills is also moderate. The results also showed a positive correlation between metacognitive thinking skills and decision-making skills.

Study Procedures

The procedures and method of the current study are as follows:

Study method

The study proceeded, in its attempt to answer its questions, according to the quasi-experimental approach that relies on a one-group associated with the process of measuring the effectiveness of teaching according to the STEM approach and its effectiveness with dependent variables, and it is a scale of decision-making and metacognitive thinking, through its application before and after.

Training program

Taking into account the guide approved by the Ministry of Education for activities, and the facilitator's guide (teacher) for implementing activities according to the STEM approach, after reviewing the literature related to the design of STEM programs and their components, such as Carter (2013). Where various activities and many topics in (Mathematics, Engineering, Science, and Technology) were chosen to teach students in a way that raises their questions and thinking and works to encourage them and consolidate the methodology of scientific research, to implement it in the university's laboratories, halls, and workshops according to the STEM approach, and the design of educational activities takes into account the complementary relationship between sciences, and many meetings were held to ensure that the STEM approach was followed in implementing activities Also, to ensure the effectiveness of the STEM approach in developing skills (decision making, metacognitive thinking) in the implementation process, the following points were taken into account:

- A guide designed by the two researchers, which contains (a brief about STEM, a brief about the targeted skills, general guidance for the teacher, a model plan to guide the implementation of activities, suggested references about STEM, and an introduction to the activities according to the STEM approach).

- It was agreed that the Academic Committee (teachers of various subjects) would select activities and project ideas to be implemented in an integrative way, and it was taken into account in their implementation to maintain the integrative relationship between the different subjects.
- Taking into account highlighting the complementarity between STEM topics and the role of each in serving the other, the two researchers continuously followed the course of the training days.

Study population and sample

The population of this work consists of all students in grades (7, 8, and 9) in public schools in Tulkarm and Qalqilya governorates, number (19,704) male and female students, in the academic year 2020-2021. This stage was targeted according to the suitability of their age characteristics to the requirements of STEM approach experience, the availability of curiosity in the surrounding environment, scientific inclinations, the attempt at personal independence, and the pursuit of excellence. Thus, it can contribute to the development of metacognitive thinking and increase their decision-making capacity. The research sample was limited to (59) male and female students as a sample of students participating in the program of teaching various sciences in an integrated manner through the STEM approach. The distribution of the sample regarding to demographic variables (Table 1)

TABLE (1) DISTRIBUTION OF THE STUDY SAMPLE ACCORDING TO THE VARIABLES OF GENDER AND PLACE OF RESIDENCE

Variables[1]	Level	Frequency	%
Gender	Male	27	45.8%
	Female	32	54.2%
Total		59	
Residence place	City	31	52.5%
	Village	28	47.5%
Total		59	

Study instruments:

The study instruments consisted of two scales:

1. Preparing a decision-making scale: Initially, after reviewing previous studies and literature on decision-making skills, and being informed by the opinions contained therein, to determine the appropriate partial skills to be developed through the training program according to the STEM approach. The item that will be included in the scale was determined, noting that the scale included items that measure the following partial skills (diagnosing the problem, generating alternatives, evaluating alternatives, and making the appropriate decision). It was taken into account that each skill includes a set of life situations followed by a set of scientific alternatives, which requires the student to choose the most appropriate alternative among them and suggest alternatives. After reviewing and revising all test items and verifying that they were free of overlap and complexity in terminology and meaning, the psychometric properties of the scale were verified.

- Content validity of the scale: The components of the decision-making scale were presented in their initial form some of arbitrators specialized in the educational field and technologies, with the aim of verifying the validity of the scale, its scientific accuracy, its comprehensiveness of the targeted skills, and its ability to measure what it was designed to measure, their constructive opinions and suggestions had an impact on producing the scale in its final form. It contained (10) situations (problems), the first page of the scale consisted of instructions to the students explaining what was required of them to respond to the scale's questions.

- Stability of the scale: the decision-making scale was applied to a survey sample, and after correcting the answer to the skills according to the previously estimated scores, Cronbach's alpha coefficient was calculated, which amounted to (0.79), which is a good stability coefficient and indicates the reliability of the results for the scale.

- Correction of the scale: the question includes a text (situation) on a specific problem, then followed by a question related to this situation that needs to be answered, followed by five alternatives, one of which the student chooses. Taking into account that the alternatives are different from each other, random, and not within a specific format, then it is sometimes followed by the reason for choosing this alternative. After correcting the test and monitoring the total score, it is converted from (5) to be consistent with the general format of the statistical analyses followed.

2. Preparing a scale of metacognitive thinking: to determine the level of metacognitive thinking among members of the study sample, the researchers developed the metacognitive thinking scale after referring to research and studies that contained previous scales, such as the study of Al-Khawaldeh, 2003; Sarver, 2006; Gama, 2004; and Bacon, 1993. The items that will be included in the scale for metacognitive thinking were determined to measure the following partial skills (planning, monitoring and control, and evaluation).

- Validity of the metacognitive thinking scale: To verify the scale which includes metacognitive thinking skills, it was presented to a group of educational and psychology experts who teach at the master's and bachelor's levels in some universities. The modifications were made in light of what was recommended by the arbitrators, so that in its final form it consisted of (22) items, in front of each item a five-point scale, and the items were distributed according to the dimensions of the scale mentioned above.

- Stability of the Metacognitive Thinking Scale: It was verified by (Test-Retest) on an investigative sample that was outside the sample of our work study. It was applied with a time interval of two weeks, after which the correlation coefficient was calculated to calculate the stability coefficient, which amounted to (0.81). Thus, the scale is considered appropriate for the purposes of the current study.

Results and Discussion

Results related to the 1st question:

(T) value for the paired samples and their statistical significance, as well as the effect size by using the Eta squared (μ^2) to identify the effect size on the dependent variable, all results displayed in Table (2)

TABLE (2) T-TEST RESULTS OF PRE-AND POST-APPLICATION OF THE DECISION-MAKING SCALE (N=59)

		Arithmetic average (AMA)	Standard deviation (SD)	T	DF	Correlation coefficient	Significance level	μ^2
Diagnosing the problem	pre-application	2.2508	.24521	-24.827	58	0.091	0.001	0.91
	post-application	3.3763	.27059					
Generating alternatives	pre-application	2.3220	.28288	-23.440	58	0.098	0.001	0.90
	post-application	3.3966	.23923					
Evaluating alternatives	pre-application	2.2712	.26720	-23.205	58	0.120	0.001	0.90
	post-application	3.4068	.20330					
Making the appropriate decision	pre-application	2.3864	.22853	-25.119	58	0.064	0.001	0.91
	post-application	3.3763	.21362					
Decision-making scale	pre-application	2.3076	0.13921	-47.287	58	0.19	0.001	0.93
	post-application	3.3890	0.10831					

It is noted from the results in Table (2) that there are statistically significant differences at ($a \leq 0.05$) level and in favor of the post-application of the decision-making scale, which indicates the positive effect of the applied program (application of STEM activities) on the decision-making scale and its dimensions (diagnosing the problem, generating alternatives, evaluating alternatives, making the appropriate decision). It is also noted that the arithmetic average for the post-application of the decision-making scale reached (3.389), which means that there are statistically significant differences in the decision-making scale (in all its dimensions) in favor of the post-application. It is also clear from Table (2) that the effect size of the applied program was large on all dimensions, and its value on the decision-making scale was (μ^2=0.93), which indicates a large explained variance and that the application of the training program has helped to develop the decision-making skills of the research sample, refine them and emphasize their importance.

The researchers explain the current result that the STEM strategy represents one of the strategies that have a positive effect on improving the quality of education. The STEM approach is a modern educational event, rich in training activities and events that are actually applied, which makes participating students more passionate and interested in educational materials, which raises their level of motivation and enthusiasm towards participating and acquiring higher thinking skills, as well as empowering them with decision-making skills, where they have the ability to identify, recognize and define the problem, and it represents a diagnosis of the problem, then they work to find various solutions and alternatives as solutions to the problem and work to examine and evaluate these solutions and alternatives to choose the most suitable alternative for the solution, and then make the decision that will be appropriate, and this is what the results of their training on the program showed through the results of the post-application.

Our results are agreed with the study of Abu Thantain, 2021, and the study of Wahono et al. (2021), where the training program based on the STEM approach in the post-application affected the level and total score in decision-making skills.

Results related to 2nd question:

T-value for the paired samples and their statistical significance, and μ^2 to find out the effect size on the dependent variable shown in Table (3).

TABLE (3) RESULTS OF THE T-TEST OF THE PRE-AND POST-APPLICATION OF THE METACOGNITIVE THINKING SKILLS SCALE (N=59).

		AMA	SD	T	DF	Significance level	Correlation coefficient	μ^2
Planning	pre-application	2.3597	0.16550	-39.36	58	0.001	0.57	0.82
	post-application	3.4350	0.13885					
Monitoring and control	pre-application	2.4867	0.15943	-28.25	58	0.001	0.15	0.77
	post-application	3.4140	0.21987					
Evaluation	pre-application	2.5141	0.21507	-24.06	58	0.001	0.15	0.75
	post-application	3.4068	0.17582					
Metacognitive thinking scale	pre-application	2.3943	0.12380	-47.64	58	0.001	0.27	0.91
	post-application	3.4293	0.12175					

Table (3) presented the statistically significant differences at ($a \leq 0.05$) level and in favor of the post-application of the metacognitive thinking scale, which indicates the positive effect of the applied program (application of STEM activities) on the scale of metacognitive thinking and its dimensions (planning, monitoring, and control, evaluation). It is also noted that the arithmetic average for the post-application of the metacognitive thinking scale reached (3.4293), which means that there are statistically significant differences in the metacognitive thinking scale (in all its dimensions) in favor of the post-application. Also, it is clear from Table (3) that the effect size of the applied program was large on all dimensions, and its value on the metacognitive thinking scale was ($\mu^2 = 0.91$), which indicates a large explained variance and that the application of the training program has helped to develop and refine the metacognitive thinking skills of the research sample and emphasize their importance.

The researchers explain the current result that the main goal of the STEM approach is to encourage students to pursue the scientific subjects that make up the approach, and these subjects require teaching thinking and using higher-order thinking methods, strategies, and skills that work and activate the mind. One of the most important ways of thinking is metacognitive thinking skills, and students demonstrated the ability to acquire metacognitive thinking sub-skills, which constitute a training framework for this skill that begins with planning, by feeling the existence of the problem, identifying it, clarifying its nature, determining the desired goal, and choosing a strategy to implement the solution through a monotonous series of steps. Needing to pay attention to the difficulties and errors identify them, and determine methods to confront these difficulties limited to a time frame, with a prediction of the desired results and desired ambitions. After acquiring the skill of planning, he moves to the skill of control and monitoring that enables him to consider his goal as the focus of his attention, to continue with the monotonous series of steps, and to be aware of each sub-goal that is achieved. And to determine the process of moving to the next step, and to continue facing difficulties, mistakes and solving them, and he moves on to the last sub-skill, which is evaluation, evaluating the achievement of goals, accurately estimate results, and evaluating the suitability of the methods used. This raises students' awareness of their thinking style and knowledge of how they think, and this is what

was shown by the results of the post-application in developing and improving the thinking style of the students who participated in the study sample.

The results of the current study agreed with the study of Nasr, 2021, in that the post-application of the STEM-based learning program had a positive effect on the study sample members.

Results related to the 3rd question:

T-value for independent samples and their statistical significance shown in Table (4)

TABLE (4) AMA, SD, AND T-TEST OF THE SAMPLE MEMBERS' RESPONSES ON THE DECISION-MAKING AND METACOGNITIVE THINKING SCALE ACCORDING TO THE GENDER VARIABLE.

	Gender	NO.	AMA	SD	T	Significance level
post-application of the decision-making skills	male	27	3.3611	0.0934	-1.853	0.069
	female	32	3.4125	0.1157		
Post-application of metacognitive thinking	male	27	3.4328	0.1467	0.200	0.842
	female	32	3.4264	0.0983		

Table (4) displayed that the value of (T) is not statistically significant at the ($\alpha \leq 0.05$) level and this means that there are no statistically significant differences at the significance level ($\alpha \leq 0.05$) in the averages of the research group's response to the post-application of the decision-making skills and metacognitive thinking skills scale due to the gender variable. This result can be explained by the fact that students participating in training on the STEM approach to learning based on higher-order thinking skills are exposed to the same training, events, and activities regardless of their social type or gender. Rather, they are in the same groups side by side receiving this training, with sufficient space given to each person to receive and satisfy the skills that constitute a goal for which the students are trained. The current result showed that there is no difference between a male or a female in learning, receiving, and acquiring these skills and this indicates the effectiveness of the training program based on the STEM approach and for the specific age stage, which is the upper elementary stage (seventh, eighth, and ninth).

The results of the study consented with the results of Altan et all, 2018, Wahono et al, 2021, and Nasr study 2019, in the post-application to develop metacognitive thinking skills and decision-making skills through a STEM-based learning program.

Results related to the 4th question:

Table (5) shows the results of the t-value for independent samples and their statistical significance.

TABLE (5) AMA, SD, AND T-TEST OF THE SAMPLE MEMBERS' RESPONSES TO THE SCALE OF DECISION-MAKING AND METACOGNITIVE THINKING DUE TO THE VARIABLE OF RESIDENCE PLACE.

Scale	Residence place	NO	AMA	SD	Tvalue	Significance level
post-application of the decision-making skills	City	27	3.3611	0.09337	-1.853	0.069
	Village	32	3.4125	0.11570		

Post-application of metacognitive thinking	City	31	3.3710	0.10310	-1.354	0.181
	Village	28	3.4089	0.11226		

Table (5) presented the value of (t) is not statistically significant at the significance level ($\alpha \leq 0.05$). This means that there are no statistically significant differences at the significance level ($\alpha \leq 0.05$) in the averages of the research group's response to the post-application of the scale of decision-making skills and metacognitive thinking skills due to the variable of place of residence. This result can be explained by the fact that societies in general and Palestinian society, in particular, have become small villages in the hands of the members of these societies due to contemporary technology and the spread of social media sites, which dissolved many of the differences between rural and urban areas, while some differences remained that there is no room to mention here. As for learning and teaching, these differences have become invisible, with the availability of schools in villages and the proximity of the village to the city due to the abundant availability of means of transportation and communication. There is no difference in teaching and learning between students depending on their place of residence, especially since they meet together in training and teaching-learning groups, in addition, Palestinian society is a homogeneous society that is not large and heterogeneous with regard to education.

Results related to the 5th question:

To answer this question, we used Pearson correlation coefficient to identify the relationship between the post-application of the decision-making scale and the metacognitive thinking scale among students who studied according to the STEM approach. The results were according to Table (6).

TABLE (6) PEARSON CORRELATION COEFFICIENTS AND ITS STATISTICAL SIGNIFICANCES BETWEEN THE POST-APPLICATION OF THE DECISION-MAKING SKILL AND METACOGNITIVE THINKING SKILLS (N=59)

Sub-skill of decision-making	Correlation coefficients and their statistical significances	Sub-skill of metacognitive thinking			Total score of metacognitive skill
		Planning	Monitoring and control	Evaluation	
Diagnosing the problem	Correlation coefficient	0.300*	0.269*	0.474*	0.283*
	significance level	0.021	0.006	0.050	0.030
Generating alternatives	Correlation coefficient	0.186*	0.283	0.188	0.213
	significance level	0.019	0.043	0.507	0.039
Evaluating alternatives	Correlation coefficient	0.156	0.262*	0.560	0.317*
	significance level	0.072	0.045	0.028	0.048
Making the appropriate decision	Correlation coefficient	0.176	0.761	0.578	0.508
	significance level	0.083	0.015	0.005	0.041
Total score of decision-making skill	Correlation coefficient	0.521*	0.411*	0.460*	0.48*
	significance level	0.041	0.046	0.035	0.044

*A statistically significant relationship at ($\alpha \leq 0.05$) level

From Table (6), it was found that the correlation coefficient for the total score for the level of decision-making skill and metacognitive thinking skill is equal to (0.48), with a probability value of (0.044), which is less than (0.05), which indicates the presence of a positive, but moderate, correlation.

The researchers explain the current result by logic, where the decision-making skill based on steps starts from recognizing, identifying, and diagnosing the problem, then developing the various alternatives available to solve it. Then identifying and choosing the appropriate and optimal alternative to the solution, implementing and evaluating the solution, and working to solve the problem, which indicates a positive correlation, but moderate. It intersects with metacognitive thinking skills that start from the planning skill, in which the individual must make decisions in identifying the problem, setting the goal, identifying appropriate alternatives, identifying difficulties, detecting errors, and working to solve them. The skill of monitoring and control through activities that seek to maintain the goal as a focus of attention, and in monotonous and sequential steps, knowing when each sub-goal is achieved, how to move from one stage to the next, detecting and correcting errors, and then moving on to the skill of evaluation.

These sub-steps in the decision-making skill and the sub-skills in metacognitive thinking skills are linked to a relationship that develops one another, that is, a positive correlation, as the first increases, the other increases. It makes STEM approach training consistent, useful, and worthy of adoption by the Ministry of Education to improve the quality of teaching and learning, especially in STEM subjects (Science, Mathematics, Engineering, and Technology). As for the level and degree of the relationship is moderate, this may relate to the age stage: middle childhood, i.e. the upper elementary stage (seventh, eighth, and ninth). However, it can be predicted that this age group's acquisition of such skills (decision-making skills and metacognitive thinking skills) will provide societies with generations capable of innovation, creativity, and increased ability to achieve and produce.

This result agreed with Nasr's 2019 study, which showed the existence of a positive, statistically significant correlation at a moderate level. It differed from the study of Akaydın et al. 2020, as it showed a statistically significant positive correlation at a weak level.

CONCLUSION

Through the theoretical framework and our finding, the researchers highlight the following conclusions:

- The use of STEM methodology had an effective and positive effect on the development of decision-making skills, as well as its positive effectiveness in the development of metacognitive thinking.
- The possibility of adopting the STEM methodology in classrooms, as it contributes to making the student the focus of the educational learning process. It gives students the opportunity to learn in new ways that raise their level of confidence in themselves and their decisions and encourages discovery and knowledge of the developments around them in order to shape their future and achieve their goals, which generates excitement and suspense, then the desire and motivation to research and explore everything they study.

RECOMMENDATIONS:

Based on the current study results, the following recommendations can be made:

- Conducting subsequent studies on the effectiveness of the STEM approach in the development of other types of thinking, such as logical, geometric, and creative thinking.
- Conducting comparative studies between the STEM approach and other approaches in the development of metacognitive thinking and decision-making.
- Holding meetings and workshops for school teachers on the importance of metacognitive thinking and decision-making, and the need to develop them among their students.
- Implication the process of teaching school students co-integrative activities according to the STEM approach to develop metacognitive thinking and decision-making skills.
- Implication of some university courses for students of educational majors an expanded idea about the STEM approach and its importance in developing different patterns of thinking.

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