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The power of STEAM activities in enhancing the level of metacognitive awareness of mathematics among students at the primary stage

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Abstract
This study aimed to investigate the effect of STEAM (science, technology, engineering, arts, and mathematics) activities in enhancing the level of metacognitive awareness of mathematics among students at the primary stage. The study used a quasi-experimental design. The researchers used the metacognitive awareness inventory of Schraw and Dennison (1994) to assess the level of metacognitive awareness of mathematics among students at the primary stage. The sample of the study included 43 students from the third grade who were chosen randomly and divided into two groups: experimental (23) and control (20). The results showed that students who learned mathematics through STEAM activities had a greater awareness of metacognition than those who learned mathematics traditionally. The study recommended using STEAM activities in mathematics classes and investigating the effectiveness of learning using STEAM activities on metacognitive awareness in other scientific subjects and for different educational levels..

Keywords: STEAM activities, metacognitive awareness, mathematics

INTRODUCTION

Modern educational trends emphasize a student-centered and constructive approach to teaching students 21st century skills, the most important of which are the development of mental and metacognitive abilities, in addition to problem-solving abilities. These trends highlight the importance of teaching subjects in a consistent and integrated manner, with mathematics being one of the most important among these subjects because mathematics helps to develop logical reasoning skills. Learners use mathematics as a tool for understanding the world and developing the society in which they live. Many students regard mathematics as a difficult subject (Cekirdekci, 2020), even though the purpose of teaching mathematics is to develop knowledge and skills to assist students in making sense of the physical and social worlds.

STEAM (science, technology, engineering, arts, and mathematics) activities, which depend mainly on integrating the arts into STEM to reshape education in the sciences and humanities, have emerged. They are then supported by trans-disciplinary frameworks within which real-world problems can be solved (Bassachs et al., 2020; Madden et al., 2013). It also enables students to learn cooperatively through "learning by doing" (Hsiao & Su, 2021). As a result, these types of learning environments complement the goals of twenty-first century. Innovation, design, and creative thinking are the means for improving life and solving problems (Khine & Areepattamannil, 2019). A study by Kim et al. (2019) also showed that math-focused STEAM education is needed to improve math skills.

According to Dejarnette (2018), there is a need for STEAM education in early childhood. Children at this age naturally gravitate toward science because of their inherent curiosity and creativity. Yakman and Lee (2012) found that STEAM enables children to create portfolio texts that reflect their current knowledge, solve relevant real-world problems that motivate them, and deeply embed their new knowledge. On the other hand, Bakkaloglu (2020) found that metacognition, as well as metacognitive skills and habits in the classroom, are crucial for students of all ages. Because of this, it was suggested that similar research be done to see how students' metacognitive awareness grows. This would help with planning for education.

The researchers decided to investigate the power of STEAM in increasing the metacognitive awareness level of mathematics among students at the primary stage.

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Contribution to the literature

- This study adds to the limited literature about enhancing metacognitive awareness of mathematics among primary students.
- In the study, steam activities were suggested to enhance mathematics metacognition among primary school students.
- An approach for teaching mathematics through steam activities in primary classrooms was presented in the study.

This step was due to the importance of metacognitive awareness and the fact that STEAM education programs are still in the start and are unfamiliar to many early childhood and primary students.

THEORETICAL FRAMEWORK

STEM vs. STEAM

STEM was developed to address students' difficulties once they have finished their coursework (Bybee, 2013). It helped them to be more capable of solving problems and facing the challenges of the times. The most important thing for STEM to be used inside classrooms efficiently is the individual's possession of 21st century skills in addition to their experience.

STEM combines functionally different disciplines in an interdisciplinary approach to solve problems that put society and its people under pressure. Yilmaz and Ayaz (2002) also regarded STEM as an approach that increases individuals' knowledge and experience, boosts their creativity, and predisposes them to solve problems by making interdisciplinary connections to the situations they encounter in their daily lives.

STEAM approaches that incorporate arts into STEM are significant and are regarded as transformative curricular and pedagogical approaches (Belbase, 2019). Using STEAM, teachers can combine a variety of skills at the same time, thereby creating learning experiences that allow children to investigate, question, research, discover, and practice original building skills (Jones, 2011), thus facilitating meaningful engagement between students and teachers (Belbase et al., 2021). Interdisciplinary STEAM education brings various disciplines together around a common theme, while each discipline retains its own identity (Jantakun et al., 2021). According to Shatunova et al. (2019), STEAM education is feasible at all levels of education, from preschool to professional, but in particular in the early childhood STEAM approach. As a tool for early childhood educators, the arts are regarded as a way to encourage children to express their ideas through various creative means (Jamil et al., 2018).

STEAM components include an integrated approach to learning that requires a conscious connection between standards, assessments, and lesson design. STEAM's core standard encourages inquiry and collaboration while emphasizing a project-based learning approach that incorporates the originality of the art curriculum (Hawari & Noor, 2020).

Although the study of Akturk and Demircan (2017) confirmed the importance of the arts in inspiring children to express themselves creatively. Integrating arts into STEM disciplines is a new research topic for early childhood education, and STEAM education lacks empirical research (Ge et al., 2015). Furthermore, a study by Aguilera and Ortiz-Revilla (2021) recommended that more experimental studies be conducted in STEM and STEAM classrooms.

According to previous literature, the early childhood level of education is viewed as the starting point for STEAM education. Children are born scientists, and the objects and events that surround them fascinate every child. Thus, the researchers believe that at this stage, they should concentrate on teaching using STEAM activities to improve the level of their various cognitive skills.

Cognitive vs. Metacognitive Awareness

Cognitive processes have an impact on every aspect of life, school, and work. Some specific uses for these cognitive processes include learning new things and making correct decisions. Its content improves cognitive abilities rather than academic abilities, such as reading, written language, or mathematics, (Pasnak, 2019). Furthermore, research in cognitive areas has expanded by referring to a wide range of concepts. One of the subjects studied in conjunction with a cognitive process is metacognitive awareness. Duman (2018) defines metacognition as "thinking about thinking". Clearly, metacognition is being aware of and controlling one's thought processes. Metacognition is essential for successful learning. It is recognized as a key concept in learning as well as a powerful predictor of academic success.

An individual's understanding of their own thinking processes and strategies, as well as their ability to monitor and regulate these processes, is referred to as metacognitive awareness (Bulut, 2018). According to Akin (2016), metacognitive awareness improves success. Thus, learners who are aware of their metacognitive skills organize and monitor their learning processes better than individuals who are unaware of their metacognitive skills (Aktag et al., 2017).

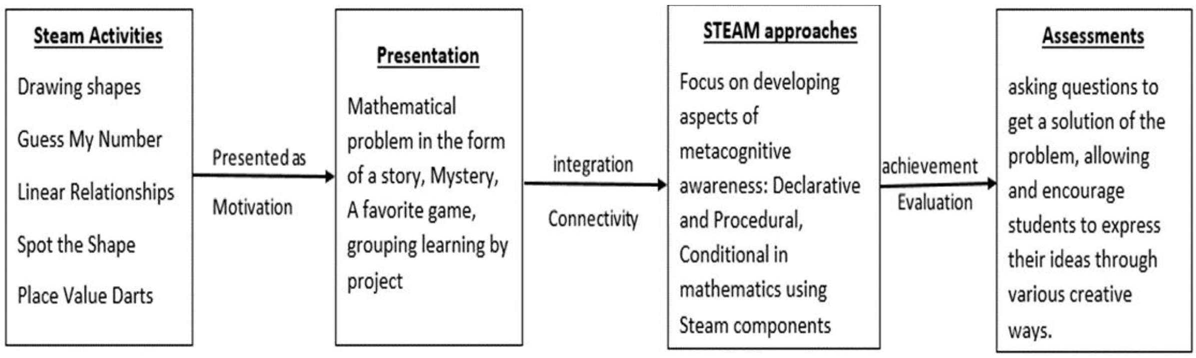

Figure 1. STEAM activities model to enhance students' _metacognitive awareness of mathematics (Source: Authors' own elaboration)

Because metacognitive awareness influences the amount of success in school, it is vital to look for new ways to help develop it as a learnable skill. Perhaps the integrated activities of STEAM will enable learners to increase this skill efficiently and effectively.

STEAM Activities

Many institutions have been keen to design learning activities according to the STEAM approach. Here, we review the activities used to investigate how learning mathematics according to STEAM impacts students' metacognitive awareness. According to Sphero (2021), the activities were selected according to their relevance to the mathematical materials taught to students, they have also been adapted to the Arab environment.

First activity: Drawing 2D and 3D shapes

This activity aims to help students identify and describe shapes and differentiate between two and three-dimensional shapes. In addition, they can combine simple shapes to create larger shapes. They can also create and run drawing program. To apply this activity, a real problem was given to the teacher, and subsequent questions were asked to direct the students to think step by step, identify important information, and brainstorm several options for getting multiple shapes and larger shapes.

Second activity: Guess My Number

This activity is designed to assist the learner to decide what the correct number is. The ability to visualize the learner's daily cause-and-effect relationship and the guessing game is in the daily life of the learners. During the activity, the teacher asked the students to think deeply and search for meaningful relationships between numbers, to change their thinking strategies when they do not know the number, and to ask for help when they do not know the number twice within a specified timeframe.

Third activity: Linear relationships

This activity aims to observe the relationship between time and distance, as well as the ability to use time, speed, and distance to explore linear relationships. In this activity, the teacher told a story to the students and asked them to draw signs when they knew what was going to happen next, then asked them to recount the steps incrementally to reach the end.

Fourth activity: Spot the shape

This activity is intended to help the learner draw and recognize basic shapes In a puzzle game, students are asked to answer additional questions when they do not know the shape, following the time instructions and asking questions in the correct order.

Fifth activity: Place value darts

This activity is designed to assist learners to construct large numbers using darts. They will add, think, and strategize to arrive at the highest possible number. The team with the highest numbers wins. The students were divided into groups, and they had to motivate themselves, think deeply, and be aware of the rules of play before beginning, brainstorm several ways to group numbers together, choose the highest number, cooperate with each other, and exchange roles to complete the task.

Figure 1 shows how STEAM activities enhance the level of metacognitive awareness of mathematics among students at the primary stage.

Purpose and Study Questions

This study aimed to investigate the effect of STEAM activities on the level of metacognitive awareness of mathematics among students at the primary stage'. To achieve this goal, the researchers try to answer the following questions:

1. Is there a significant difference between the experimental group's pre-metacognitive awareness (Pre-MAI) and post-metacognitive awareness (post-MAI) levels of mathematics in terms of STEAM activities?
2. Is there a significant difference between the control groups' pre-metacognitive awareness (Pre-MAI) and post-metacognitive awareness

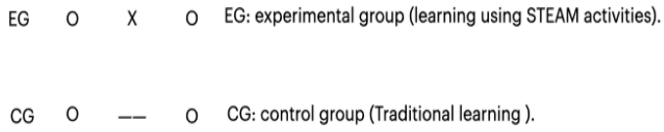

Figure 2. Study design (Hsiao & Su, 2021)

(post-MAI) levels of mathematics in terms of STEAM activities?

3. Is there a significant difference between the post-metacognitive awareness (post-MAI) levels of the experimental and control groups in terms of STEAM activities?

METHOD

Research Design

The researchers used a quasi-experimental design with the pre-/post-test control group in the study.

According to the model chosen, the independent variable was the instructional approach (teaching by STEAM activities vs. traditional teaching). The dependent variable was the level of metacognitive awareness of mathematics among students at the primary stage, which was assessed using the metacognitive awareness inventory (MAI) of Schraw and Dennison (1994) over a period of 10 weeks. **Figure 2** shows the study design.

Participation

The sample of the study consisted of 43 students from the third grade, who were randomly selected and distributed into two groups: experimental (23) and control (20).

Instruments

The researchers used the MAI instruments. The MAI, developed by Schraw and Dennison (1994), was used to evaluate the level of metacognitive awareness of mathematics among students at the primary stage. The MAI is a 52-item scale with two main components and eight sub-components. The first main component is knowledge of cognition, and it includes (declarative knowledge, procedural knowledge, and conditional knowledge). The second one is regulation of cognition, and it includes (planning, information management strategies, comprehension monitoring, debugging strategies, and evaluation) (Schrow & Dennison, 1994).

The knowledge of cognition components includes 17 items and measures awareness of one's strengths and weaknesses, knowledge about strategies, and why and when to use those strategies. The regulation of cognition components includes 35 items and measures knowledge about one's planning, implementing, monitoring, and evaluating strategies. The MAI does not contain any negative items. The highest score that a student can obtain from this inventory is 52, and the lowest score is zero. Declarative knowledge (out of eight), procedural knowledge (out of four), conditional knowledge (out of five), planning (out of seven), information management strategies (out of 10), comprehension monitoring (out of seven), debugging strategies (out of five), evaluation (out of six), and overall (out of 52)

Validity and Reliability

Cronbach's alpha internal consistency coefficients were calculated as 0.96 for the original version of the MAI (Schrow & Dennison, 1994). To verify the instrument's validity, the researchers presented it to academics specializing in STEAM research, then applied it to a pilot sample of 30 students to assess its reliability. This instrument has a Cronbach's alpha coefficient of 0.82 overall, 0.78 for knowledge of cognition, and 0.81 for regulation of cognition, indicating it is valid to apply.

Data Analysis

The researchers used the Kolmogorov-Smirnov goodness-of-fit to test the normality of the data. On the other hand, they used Levene's test to test the hypothesis of variance homogeneity. Based on the results of the Kolmogorov-Smirnov goodness of fit test, and Levene's test, parametric tests were chosen. A paired sample t-test was used for pre- and post-test comparisons within the groups. An independent sample t-test was used to draw comparisons between the experimental and control groups. The statistical analysis of the study was conducted using the SPSS statistical package for all statistical decoding. The significance level was set at 0.05.

RESULTS

Normality and Homogeneity of the Distribution

The normality and homogeneity of the distribution were checked by Kolmogorov-Smirnov and Levene's tests and the results were displayed.

Table 1 presents the results of the Kolmogorov-Smirnov goodness-of- fit test on the pre- and post-MAI scores from the MAI of the experimental and control groups.

As **Table 1** shows, the pre- and post-MAI scores obtained by the experimental and control groups as overall and within the components of MAI revealed normal distribution at ($p>0.05$)

Table 2 shows variances in the pre- and post-MAI scores from the experimental and control groups from the overall and components of MAI revealed homogeneity.

In general, the results of the Kolmogorov-Smirnov goodness-of-fit and Levene's tests revealed that the

Table 1. Kolmogorov-Smirnov test results on the pre- & post-MA scores from the MAI of the experimental & control groups

Domain	Sub-domain	Test	Group	Kolmogorov- Smirnov	p-value
Knowledge of cognition	Declarative knowledge	Pre-MAI	Experimental	0.281	0.157
			Control	0.238	0.074
		Post-MAI	Experimental	0.202	0.065
			Control	0.301	0.063
	Procedural knowledge	Pre-MAI	Experimental	0.372	0.200
			Control	0.281	0.130
		Post-MAI	Experimental	0.223	0.079
			Control	0.239	0.144
	Conditional knowledge	Pre-MAI	Experimental	0.321	0.513
			Control	0.233	0.160
		Post-MAI	Experimental	0.250	0.075
			Control	0.231	0.078
Regulation of cognition	Planning	Pre-MAI	Experimental	0.250	0.318
			Control	0.267	0.263
		Post-MAI	Experimental	0.273	0.088
			Control	0.274	0.283
	Comprehension monitoring	Pre-MAI	Experimental	0.364	0.209
			Control	0.323	0.299
		Post-MAI	Experimental	0.206	0.144
			Control	0.220	0.277
	Evaluation	Pre-MAI	Experimental	0.233	0.410
			Control	0.221	0.670
		Post-MAI	Experimental	0.209	0.940
			Control	0.214	0.720
	Debugging strategies	Pre-MAI	Experimental	0.201	0.270
			Control	0.260	0.310
		Post-MAI	Experimental	0.187	0.250
			Control	0.242	0.910
	Information management strategies	Pre-MAI	Experimental	0.214	0.790
			Control	0.176	0.720
		Post-MAI	Experimental	0153	0.470
			Control	0.160	0.310
Overall		Pre-MAI	Experimental	0.129	0.200
			Control	0.127	0.200
		Post-MAI	Experimental	0.167	0.144
			Control	0.115	0.200

Table 2. Levene's test results on the pre- & post-MAI scores from the MAI experimental & control groups

Domain	Sub-domain	Test	F	df_1	df_2	p-value
Knowledge of cognition	Declarative knowledge	Pre-MAI	0.325	1	41	0.570
		Post- MAI	0.640	1	41	0.830
	Procedural knowledge	Pre-MAI	0.154	1	41	0.830
		Post- MAI	0.077	1	41	0.610
	Conditional knowledge	Pre-MAI	0.154	1	41	0.780
		Post- MAI	0.297	1	41	0.697
Regulation of cognition	Planning	Pre-MAI	0.128	1	41	0.722
		Post- MAI	0.256	1	41	0.616
	Comprehension monitoring	Pre-MAI	0.062	1	41	0.992
		Post- MAI	0.233	1	41	0.823
	Evaluation	Pre-MAI	1.770	1	41	0.196
		Post- MAI	0.226	1	41	0.091
	Debugging strategies	Pre-MAI	1.250	1	41	0.300
		Post- MAI	2.990	1	41	0.212
	Information management strategies	Pre-MAI	0.430	1	41	0.952
		Post- MAI	0.170	1	41	0.980
Overall		Pre-MAI	0.180	1	41	0.604
		Post- MAI	0.990	1	41	0.995

researchers could use parametric tests to analyze the data obtained from the research.

Table 3 shows the results of the independent sample t-test on pre-test scores for the experimental and control groups from MAI.

Table 3. Independent samples t-test results on pre-test scores from the MAI of the experimental & control groups

Domain	Sub-domain	Group	n	$\bar{X}$	SD	T	df	p-value
Knowledge of cognition	Declarative knowledge	Experimental	23	1.20	0.99	-1.48	41	0.148
		Control	20	0.80	0.83		41	
	Procedural knowledge	Experimental	23	0.83	0.78	-1.75	41	0.088
		Control	20	0.45	0.60		41	
	Conditional knowledge	Experimental	23	0.87	0.87	-0.82	41	0.415
		Control	20	0.65	0.88		41	
Regulation of cognition	Planning	Experimental	23	1.22	1.20	-0.61	41	0.546
		Control	20	1.00	1.12		41	
	Comprehension monitoring	Experimental	23	1.26	0.92	-0.21	41	0.832
		Control	20	1.20	0.95		41	
	Evaluation	Experimental	23	1.78	0.90	0.06	41	0.953
		Control	20	1.80	1.00		41	
	Debugging strategies	Experimental	23	2.91	1.44	-0.23	41	0.823
		Control	20	1.90	1.21		41	
	Information management strategies	Experimental	23	1.48	1.08	-1.06	41	0.297
		Control	20	1.15	0.93		41	
Overall		Experimental	23	9.80	3.20	-1.83	41	0.075
		Control	20	8.10	2.80		41	

Table 4. Paired sample t-test results on pre- & post-test scores from the MAI of the experimental groups

Domain	Sub-domain	Group	n	$\bar{X}$	SD	T	df	p-value
Knowledge of cognition	Declarative knowledge	Pre-test	23	1.217	0.998	-18.858	22	0.000
		Post-test	23	6.173	0.650		22	
	Procedural knowledge	Pre-test	23	2.926	0.777	-10.595	22	0.123
		Post-test	23	3.000	1.000		22	
	Conditional knowledge	Pre-test	23	0.869	0.868	-10.961	22	0.000
		Post-test	23	3.217	0.902		22	
Regulation of cognition	Planning	Pre-test	23	1.217	1.204	-12.988	22	0.000
		Post-test	23	5.173	0.834		22	
	Comprehension monitoring	Pre-test	23	1.260	0.915	-14.468	22	0.000
		Post-test	23	4.869	0.967		22	
	Evaluation	Pre-test	23	1.782	0.902	-5.348	22	0.000
		Post-test	23	3.478	1.238		22	
	Debugging strategies	Pre-test	23	1.173	1.114	-8.425	22	0.000
		Post-test	23	3.434	0.727		22	
	Information management strategies	Pre-test	23	6.478	1.281	-16.108	22	0.090
		Post-test	23	6.782	1.277		22	
Overall		Pre-test	23	9.826	3.171	-29.929	22	0.000
		Post-test	23	36.130	2.974		22	

As shown in **Table 3**, there was no statistically significant difference between the experimental and control groups' pre-MAI scores in the overall and sub-components of MAI ($t_{overall}$[41]=-1.83; $t_{declarative}$[41]=-1.48; $t_{procedural}$[41]=-1.75; $t_{conditional}$[41]=-0.82; $t_{planning}$[41]=-0.61; $t_{comprehension}$[41]=-0.21; $t_{evaluation}$[41]=0.06; $t_{debugging}$[41]=-0.23; $t_{information}$[41]=-1.06; $p>0.05$).

Paired samples t-test results of the pre- and post-test scores from the experimental groups are presented in **Table 4**.

As **Table 4** shows, a statistically significant difference was found between the total pre- and post-MAI means scores obtained from the experimental groups $t_{experimental}$(22)=-29.929, $p>0.05$. The post-test total means scores of the experimental groups ($\bar{X}$=36.130, SD=2.974) were found to be higher than the pre-MAI total mean scores ($\bar{X}$=9.826, SD=3.171). This finding indicated that the STEAM activities conducted were effective in developing the level of metacognitive awareness of mathematics among students at the primary stage. In addition, a statistically significant difference was found between pre- and post-test scores means in the subcomponents: declarative knowledge, conditional knowledge, planning, comprehension monitoring, evaluation, and debugging strategies.

The post- test means scores of the experimental group in all mentioned sub-components were found to be higher than the pre-MAI means scores ($t_{declarative}$[22]=-18.858; $t_{conditional}$[22]=-10.961; $t_{planning}$[22]=-12.968; $t_{comprehension}$[22]=-14.468; $t_{evaluation}$[22]=-5.368; $t_{debugging}$[22]=-8.425; $p<0.05$). There were no statistical differences in the procedural knowledge and information management strategies attributed to the experimental group $t_{procedural}$(22)=-10.595; $t_{information}$(22)=-16.108; $p>0.05$.

Table 5 presents the paired sample t-test results from the control groups' pre- and post- MAI scores.

Table 5. Paired sample t-test results on pre- & post–MAI scores from the MAI of the control group

Domain	Sub-domain	Group	n	$\bar{X}$	SD	T	df	p-value
Knowledge of cognition	Declarative knowledge	Pre-test	20	1.20	0.833	-3.327	19	0.094
		Post-test	20	1.250	0.966		19	
	Procedural knowledge	Pre-test	20	0.95	0.604	-3.943	19	0.101
		Post-test	20	0.9000	0.788		19	
	Conditional knowledge	Pre-test	20	0.990	0.875	-2.666	19	0.067
		Post-test	20	1.000	0.858		19	
Regulation of cognition	Planning	Pre-test	20	2.01	1.123	-5.627	19	0.138
		Post-test	20	2.0	1.337		19	
	Comprehension monitoring	Pre-test	20	1.2	0.951	-1.831	19	0.083
		Post-test	20	1.35	1.039		19	
	Evaluation	Pre-test	20	1.80	1.005	-3.199	19	0.131
		Post-test	20	1.81	1.182		19	
	Debugging strategies	Pre-test	20	1.1	1.020	-1.453	19	0.163
		Post-test	20	1.2	1.151		19	
	Information management strategies	Pre-test	20	1.88	0.933	-4.273	19	0.203
		Post-test	20	1.850	1.225		19	
Overall		Pre-test	20	11.15	2.796	-9.695	19	0.088
		Post-test	20	11.700	2.957		19	

Table 6. Independent samples t-test results on post-test scores of the experimental & control group

Domain	Sub-domain	Group	n	$\bar{X}$	SD	T	df	p-value
Knowledge of cognition	Declarative knowledge	Experimental	23	6.173	0.966	-19.826	41	0.000
		Control	20	1.250	0.650		41	
	Procedural knowledge	Experimental	23	3.0	1.0	-7.565	41	0.000
		Control	20	0.9	0.788		41	
	Conditional knowledge	Experimental	23	3.217	0.902	-8.220	41	0.000
		Control	20	1.0	0.858		41	
Regulation of cognition	Planning	Experimental	23	5.173	0.834	-9.466	41	0.000
		Control	20	2.0	1.337		41	
	Comprehension monitoring	Experimental	23	4.869	0.967	-11.489	41	0.174
		Control	20	4.90	1.839		41	
	Evaluation	Experimental	23	3.478	1.238	-3.583	41	0.001
		Control	20	2.15	1.182		41	
	Debugging strategies	Experimental	23	3.434	0.727	-7.71	41	0.000
		Control	20	1.2	1.151		41	
	Information management strategies	Experimental	23	6.782	1.277	-12.866	41	0.000
		Control	20	1.85	1.225		41	
Overall		Experimental	23	36.13	2.974	-26.936	41	0.000
		Control	20	11.7	2.957		41	

According to **Table 5**, there was no statistically significant difference between the total pre-test and post-test scores obtained from the MAI by the control group that used a traditional teaching approach ($t_{control}$[19]=-9.695; p>0.05).

The total pre-test means scores of the control group ($\bar{X}$=11.150, SD=2.796) were similar to the total post-test means scores ($\bar{X}$=11.70, SD=2.957). This finding shows that the mathematical content course conducted with a traditional teaching approach did not have a significant effect on the level of metacognitive awareness of mathematics among students at the primary stage. Furthermore, it was determined that there was no statistically significant difference in terms of the sub-components of MAI in the control group ($t_{declarative}$[19]=-3.327; $t_{procedural}$[19]=-3.943; $t_{conditional}$[19]=-2.666; $t_{planning}$[19]=-5.627; $t_{comprehension}$[19]=-1.831; $t_{evaluation}$[19]=-3.199; $t_{debugging}$[19]=-1.453; $t_{information}$[19]=-4.273; p<0.05)

Nonetheless, **Table 6** displays the independent t-test results of the post-test mean scores obtained from MAI from both groups.

As **Table 6** shows, the post-test total means scores of the experimental group ($\bar{X}$=36.130, SD=2.974) were found to be higher than the post-test mean scores of the control group ($\bar{X}$=11.7, SD=2.957). This finding indicated that the level of metacognitive awareness of mathematics among students at the primary stage in the experimental group increased more than the level of metacognitive awareness of mathematics among students at the primary stage in the control group ($t_{experimental}$[41]=-26.936; p<0.05).

However, a statistically significant difference was determined in all sub-components of knowledge of cognition domains ($t_{declarative}$[41]=-19.826; $t_{procedural}$[41]=-7.565; $t_{conditional}$[41]=-8.220; p<0.05). Additional significant difference was determined in the sub-components of regulation of cognition ($t_{planning}$[41]=-9.466; $t_{evaluation}$[41]=-3.583; $t_{debugging}$[41]=-7.710; $t_{information}$[41]=-12.866; $p<0.05$), accept the sub components ($t_{comprehension}$[41]=-11.489; $p>0.05$). These findings show that using the STEAM approach was more effective than using the traditional approach in enhancing the level of metacognitive awareness of mathematics among students at the primary stage, in all sub-components of knowledge of cognition and most subcomponents of regulation of cognition.

CONCLUSION AND DISCUSSION

The current study presents data on the initial levels of metacognitive awareness of mathematics among students at the primary stage in addition to a comparison of the consequences of STEAM activities versus traditional teaching approaches on participants' level of metacognitive awareness.

Conclusion One

There are no statistically significant differences between the levels of pre- and post-meta cognitive awareness among the members of the control group at the level of the general degree of awareness as well as within each of the sub-domains of the scale.

The previous result indicates a low level of metacognitive awareness among the members of the control group within the various sub-domains of the scale. This is attributed to different reasons like the weakness of linking its issues with the reality of students' lives, the use of the memorization method used in teaching, the lack of interesting and attractive teaching methods and techniques, as well as students' low motivation to learn.

The nature of the content, activities and exercises included in the books that do not help to stimulate the necessary motivation to learn, which may lead to weakness in awareness in the area of observing the understanding of learners. There is an increase in exercises with clear neglect of correction by teachers, which may lead to weakness in the field of awareness and correction strategies among students. This was confirmed by the study of Al-Akrass (2018).

This may also be due to the learner's poor awareness of the steps he may follow in solving mathematical problems. Moreover, the lack of knowledge of shapes or schemes related to specific content, the general weakness in understanding the steps of the solution and the method of dealing with the problem, are other factors that cause a decline in various areas of metacognitive awareness among students such as declarative, conceptual, procedural, and planning knowledge. This emphasizes the importance of looking for ways to help students raise their level of metacognitive awareness. Slimon's (2014) study indicated the importance of metacognitive awareness in enhancing learners' thinking. It increases learners' awareness of what they study and achieve academically as there is a link between metacognitive awareness and academic achievement.

The decline in metacognitive awareness requires a review of the educational process and its content. Moreover, there is a need to direct learners to use methods and techniques that help them in developing metacognitive awareness, which plays an important role in students' learning (Akbayir & Topcul, 2021). The study indicated a positive relationship between metacognitive awareness and increased academic achievement, particularly in mathematics.

Conclusion Two

There are statistically significant differences between the levels of pre- and post-cognitive awareness among the individuals of the experimental group at the general level of awareness and within each of the sub-domains of knowledge of cognition (declarative knowledge and conditional knowledge). This suggests that STEAM activities improved the experimental sample individuals' metacognitive awareness in the aforementioned fields. However, teaching activities according to the STEAM approach did not affect the improvement of metacognitive awareness among the experimental group members within the sub-domains of procedural knowledge and information management strategies.

This ensures that STEAM activities include many appealing stimuli and a conceptual hierarchy of activities. They are presented to students in fun and purposeful events gradually and in an appealing and interesting way that stimulates them to focus for a longer period. This helped students interact with educational situations and experiences in mathematics, and it connected them to reality by repeating them in similar situations. It also encouraged them to participate actively and effectively in the educational process This is what showed by the study by (Kermani & Aldemir, 2015; Kim & Kim, 2016; Park et al., 2016), were confirmed that emotional touch (as one of three elements and criteria of STEAM learning), includes the formation of a clear and actual relationship between the learner and the subject. Also, emotional touch engenders students' enthusiasm for challenging new problems through interest, motivation, and the joy of success. Furthermore, it implemented activities and tasks based on their comprehensive mathematical concepts STEAM activities also contributed to the use of the method of learning by doing, which worked on retaining, absorbing, and applying scientific knowledge in solving new mathematical problems and exercises.

Building models of mathematics lessons using the STEAM approach may have contributed to students remembering information and creating a kind of interest for them. Moreover, it aroused in them positive participation in work, using various materials and equipment; and immersing students in rich learning experiences that were unfamiliar to them, all of which contributed to raising the level of declarative knowledge. They have also contributed to increasing students' ability to carry out tasks in a flexible, accurate, and appropriate manner, stimulating awareness of implementing procedures for them. STEAM activities provided the element of fun, so they gave the learner enough time to focus and think before starting the task. Furthermore, they have enough time to determine the goal of the activity and focus the students' attention to perform the activity with their colleagues, which improves their planning skills and good management of their information to complete the activities assigned to them. It also helped to improve communication skills among students by asking colleagues for help when there was a glitch in a cooperative and friendly manner among them, distributing tasks and roles among them, and re-reading information in case the activity was not completed, which contributed to improving their corrective skills. This is what Cabello et al. (2021) indicated in their study and on the development of the learner's own personality. Encourage learners to ask frequent questions and to ensure mastery and quality of work, as well as considering several options to complete the activity have contributed to the extent of monitoring the students' comprehension monitoring. STEAM activities have contributed to creating a space of cooperation and participation between groups of students, where students worked together to summarize the way they plan and implement activities, present the completed work, and ask questions about the quality of work, which contributed to improving students' assessment skills. Also, the integration of appropriate technology has contributed and is expected to help engage students more in the learning process (Hwari & Noor, 2020). This is what Bahrum et al. (2017) indicated in their study.

However, the process of teaching STEAM activities did not affect the improvement of metacognitive awareness among the experimental group members within the sub-domains (2-1, 2-2). The researchers would attribute this to many reasons such as the short period of experiment implementation where some metacognitive skills require a longer time to train to acquire. Moreover, the activities may not be suitable for third-grade students because of their young age. STEAM activities may be unfamiliar to many primary schools and early classes.

Conclusion Three

There are statistically significant differences between the control and experimental groups in the level of metacognitive awareness in general and with each subdomain's: knowledge of cognition (declarative knowledge, procedural knowledge, and conditional knowledge). Regulation of cognition (planning, information management strategies, debugging strategies, and evaluation). However, there was no difference in the degree of metacognitive awareness within the domain comprehension monitoring between the two groups. This indicates that the degree of metacognitive awareness of the members of the group that studied the activities according to the STEAM approach is better than the degree of the metacognitive awareness of their peers who studied traditionally.

The researchers explain this result by the fact that the activities of STEAM activities placed the students of the experimental group in an educational environment characterized by modernity and interaction, which provided a valuable opportunity to learn according to their own speed, self-stepping, abilities, and potential. This enabled them to think consciously and deliberately. It also motivated them to solve the tasks in general and increased their level of mastery of concepts that led them to think more deeply about the steps of the solution.

STEAM activities contributed to presenting the educational material in an attractive way that helped increase their interaction with educational situations. It encouraged them to participate actively in the activities and to complete the tasks assigned to them with vigor and activity. This resulted in the ability to retain, absorb, and apply scientific knowledge in similar teaching situations and to transfer the impact of learning to other situations. In addition to creating an environment that encouraged them to test their solutions. (Al-Haj Bedar & Al-Shboul, 2020).

These activities allowed us to provide the quality of repetition several times in the case of not understanding any part of the material or not paying attention to it. This was achieved by allowing the students to cooperate and communicate with each other, and without feeling ashamed or afraid of this repetition, which enhanced their confidence in themselves. The activities were presented in a way that was in line with their needs, desires, tendencies, and developmental characteristics. Consequently, students' awareness in the areas of declarative and planning knowledge improved. They worked to increase their cognitive curiosity and gave them the desire to investigate, discover, ask questions, and think about various tasks (Dejarnette, 2018). They ensured providing them with rigid concepts tangibly via a multifaceted and multi-sensory approach to develop thinking strategies outside the box. This helped them to get innovative answers, which raised the level of their conditional knowledge (Lytra & Drigas, 2021).

This result may be attributed to the nature of the activities and tasks and the cooperative atmosphere that prevailed among the students in the classroom. The students could exchange views, watch, listen, read, ask, and learn from their peers. They also teach them and cooperate with each other to perform the task correctly. Learning cooperative and interactive activities and tasks increase, provided by extra time. Teachers give immediate feedback to students by implementing multiple class activities and tasks (Dilek et al., 2020; Ng et al., 2022).

The teacher's feedback contributes to helping students fix concepts and reach a proper understanding before the incorrect information becomes embedded in their minds. These features contribute to improving the student's efficiency, encourage him to learn, increase the level of awareness and develop correction strategies for the learner. On the other hand, the lack of a difference in the degree of metacognitive awareness within the domains (2-3) between the two groups may be because the activities do not focus specifically on developing these skills. There is a need for more time and several of activities to develop them.

Based on the findings, this study recommends using STEAM activities in mathematics classes and investigating the effectiveness of learning using STEAM activities on metacognitive awareness in other scientific subjects and for different educational levels, Increasing the number of empirical research in this field, especially with regard to cognitive skills, the development of logical thinking, problem solving and decision-making, as these are the most prominent skills of the twenty-first century necessary to meet the requirements of the digital age.

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