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Investigating the Relationship between Metacognition and STREAM Education in Science: An Exploratory Study

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Abstract: *Metacognition and STREAM (Science, Technology, Reading, Engineering and Math) education are indisputable in today's informational society for both personal and professional development. The current study aims to investigate the potential relationship between these two variables. Although there is not yet a substantial theoretical background that integrates both concepts into a coherent perspective, research on this topic can provide relevant insights on how to analyze and incorporate these concepts into a consistent theoretical and empirical paradigm. For this purpose, 3rd year students who are preparing themselves to become primary and preschool teachers participated in the study. They were given an online link to a self-reported measure of metacognition in science (the MAI scale) and an assessment task that measured how well they integrate STREAM knowledge with science-related topics. Data analysis revealed a significant relationship between metacognition and STREAM knowledge in science education. Moreover, it seems that metacognition is a significant predictor of STREAM knowledge. The results of this study are highly valuable in the context of the scarcity of research on this topic, being a starting point for the development of a theoretical perspective to explain the metacognition - STREAM education relationship.*

Keywords: *metacognition; STREAM education; science education; teacher training; prospective elementary school teachers.*

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Introduction

Science has a significant impact in various fields relevant to everyday life (e.g., sports or arts) (Ogunkola, 2013). Research (Laugksch, 2000; Ogunkola, 2013) indicates that scientific literacy is related to economic well-being, having an increasingly important role in everyone's life. In the francophone literature the expression <<la culture scientifique et technologique>> (scientific and technological culture) has been developed to highlight how strongly science entered the daily life of man (Holbrook & Rannikmae, 2009). There is a high need for innovative skills in the development of professional life and in solving daily life problems. Scientific competencies became important for all students, not just for those pursuing a science-related career.

The significant position that science gained in recent years in people's everyday life has determined researchers to focus on this domain and to integrate it with other relevant domains like technology, mathematics, or engineering. Thus, the term STEM (Science, Technology, Engineering, and Math) took an increasingly strong shape in the specialized literature and practice. After successfully integrating and applying these four areas in various fields (including industries and education), researchers went along to integrate Arts in the STEM domain (STEAM) and then Reading (STREAM). In this manner, today we can talk about STREAM education, which stands for Science, Technology, Reading, Engineering, Arts, and Math. Although reading has become essential and is included in the STREAM approach by many researchers, there are studies that are focused on Robotics or Religion instead of Reading. Badmus and Omosewo (2020) replaced the R from Reading with R from Robotics, while Makrakis (2018) includes Reflection (Reflective learning) in STREAM education, instead of Reading. Mubarok et al. (2020) believe that Religion should be included in the STREAM approach since it correlates with positive educational outcomes in Indonesian society. Both Reading and Robotics are essential today, thus there is a high probability that the STREAM field will be extended even further to include the double Rs from both reading and robotics.

STREAM education does not mean to simply identify disparate or various relations between the six domains, but to integrate them into a single structure of knowledge and skills. Research indicates that prospective elementary teachers find STEM, STEAM and STREAM approaches easy to implement in both preschool and primary school (Ciascai & Marchis, 2019). However, research related to STREAM education is at its beginning albeit

the STEM domain is quite advanced regarding its integration in the educational and organizational fields. In addition to STEM skills, reading and literacy skills are critical in the information society we live in today. To understand a science text, students need to work on reading comprehension. Nevertheless, reading is not only essential in science but also in mathematics. If teachers consider that students need to understand the text of a given problem, they will certainly focus on reading comprehension as well. Therefore, the inclusion of reading in STEAM is essential.

Although science literacy and STREAM skills hold an essential role in the contemporary daily and professional life of individuals, it seems that students are not interested in pursuing careers related to this field. In 2015, there was one of the lowest proportions of students interested in engaging in science-related careers (16%) (Cseres-Gergelyne et al., 2018). In addition to the low percentage of students interested in a STEM career, the literature also identifies gender differences related to STEM professions all over Europe, with men outperforming women in these positions. For example, in Romania but also in Bulgaria, Ireland and Estonia the percentage of women who enter occupations related to the STEM field is above 30% (Cseres-Gergelyne et al., 2018). Thus, it seems that interest and motivation for occupations related to STREAM fields are reduced among students in general and especially among Romanian students. One way to attract students to STEM-related professions would be to increase their interest and motivation towards this field and there are several ways to do this. For instance, Lefever-Davis and Pearman (2015) claim that students' interest and motivation in science increases when STEM education is integrated with problem-based learning. Moreover, Lefever-Davis and Pearman argue that problem-based learning involves the use of both cognitive and affective skills and connects the STEM field to real-life problems, thus increasing students' interest, curiosity, creativity, and innovation skills. In addition to problem-based learning, mentoring and collaborative learning are two other ways to increase students' interest and motivation in STEM-related careers. In a study of 323 students, Fifolt and Searby (2010) showed that engaging students in mentoring programs and collaborative learning prepares them for the reality of STEM-related careers with work experiences in real work environments. Another effective way to increase students' interest and skills in STEM and STREAM careers is to focus on metacognitive learning. There are studies documenting the relationship between metacognition and STEM education (Crippen & Antonenko, 2017; Redcay, 2019; Vestal et al., 2017; Wangguway et. al, 2020). However, studies incorporating STREAM education into metacognitive learning are in their infancy. Thus, we will

briefly highlight what metacognitive learning or awareness means and review studies linking it to STEM/STREAM education.

Metacognitive learning or awareness enables students to learn effectively so that they deeply comprehend what they read or watch in a lecture or audio-visual material. Since learning is a complex process, it is necessary to use specific knowledge and strategies that facilitate the understanding of the content. Metacognition enables the use of strategies such as: planning, monitoring, self-directed learning, evaluation, and reflection. Using metacognitive knowledge and skills in learning allows us to search for, select and evaluate information, choose, and assess learning strategies, and be aware of our learning strengths and weaknesses. Research shows that students who use metacognition better understand essential scientific concepts and processes and have higher positive attitudes towards science compared to those who do not use metacognition during the learning process (Ciascai & Haiduc, 2014; Jahangard et al., 2016; Mai, 2015; Wirzal. et al., 2022; Tsai. et al., 2019). Flavell's (1976) definition of metacognition is still relevant in the literature and thus metacognition can be considered as the active monitoring and regulation of cognitive processes, having two main dimensions: metacognitive knowledge and metacognitive regulation. The first dimension, metacognitive knowledge, comprises knowledge about how one learns (declarative knowledge), knowledge about learning strategies (procedural knowledge), and knowledge about how and when to use specific learning strategies (conditional knowledge) (Schraw et al., 2012; Schuster et al., 2020). The second dimension, named metacognitive regulation includes self-regulation mechanisms of the learning process. To regulate their learning, students must be actively involved in the learning process. This means consciously focusing on the strategies used during learning, identifying difficulties encountered and overcoming difficulties. Hartman (1998) believes that metacognitive control means the deliberate use of a particular learning method while Frenkel (2014) pointed out that most models of metacognition include planning, monitoring, and evaluation. To these strategies we add a fourth, self-direction, which in some models of metacognition is located between the monitoring and evaluation phases or included in the monitoring phase. Planning involves consciously choosing appropriate strategies and allocating the necessary resources to accomplish a learning task. As Schraw and Moshman (1995) noticed planning involves allocating time, anticipating, or making predictions, establishing appropriate strategies, identifying, and setting a learning goal, and managing attentional resources. Monitoring learning means checking comprehension or understanding of the task and how well that learning task has been

accomplished. The fourth dimension of metacognitive regulation involves evaluating the learning outcomes.

The impact of metacognition on learning has been documented in many studies indicating that metacognitive awareness has positive effects on learning, including motivation, interest, performance, and comprehension, in a variety of academic fields (Math, Science, Reading) (Coutinho et al., 2005; Erskine, 2009; Gott et al., 1996; Kruger & Dunning, 1999; Shunk & Ertmer, 2000; Stoeger & Ziegler, 2011). Regarding STREAM education, research on its relationship with metacognition is in its early stages. However, there are studies that have looked at the relationship between metacognition and STEM education. One such study emphasizes that metacognitive scaffolding has an essential contribution to effective cyberlearning experiences in STEM education (Crippen & Antonenko, 2017) while Vestal et al. (2017) argue that it is vital to include metacognitive teaching and learning in all STEM classrooms if we want our students to learn more effectively and enjoy this field. The role of metacognition in STEM learning was also analyzed in the research of Choy et al. (2020). Their study indicated that metacognitive knowledge and experiences have a significant influence on both quality learning and learning outcomes, for students in both STEM and non-STEM fields. Our study aims to continue and deepen research focused on the relationship between metacognition and STREAM education. Therefore, the present study is among the first to address this theme of metacognition and STREAM science education, being an exploratory-correlational study. Building on the literature attesting to the link between metacognition and STEM, as illustrated above, we hypothesized that we would also identify this relationship in the case of metacognition and STREAM education.

Methodology

Participants

A total of 109 prospective primary and preschool teachers participated in the study. At the time of the research (April-May 2023), the participants were enrolled in distance education in the 3rd year of B.A. studies at a public university in Romania. The mean age of the participants was 29.34 years, 32.7% were from rural areas and 67.3% were from urban ones. The participants are all females, a characteristic of preschool and primary education in Romania (most teachers from these levels are women).

Instruments

Metacognitive Awareness Inventory (Schraw & Dennison, 1994)

Participants filled out a self-report scale that assesses metacognitive awareness, namely the Metacognitive Awareness Inventory (MAI). The MAI was developed by Schraw and Dennison and has 52 items measured on a 5-point Likert scale (1-Strongly Disagree; 2-Disagree; 3-Neither Disagree nor Agree; 4- Agreement; 5-Total agreement). The scale has two main dimensions. The first dimension, metacognitive knowledge, includes the following scales: (1) declarative knowledge, (2) procedural knowledge, and (3) conditional knowledge. The second dimension is metacognitive regulation and has five scales: (1) planning, (2) information management strategies, (3) monitoring, (4) self-regulation strategies, and (5) learning evaluation. The internal consistency of the MAI is 0.89 for the first dimension and 0.84 for the second. The entire scale achieved an internal consistency coefficient of 0.96. Participants were asked to think about their science learning process when completing the MAI.

Individual task/assessment

The participants had to complete an individual task whose requirement is presented below:

Design an activity that integrates STREAM knowledge and skills (Science, Technology, Reading, Engineering, Arts and Mathematics) for a science topic of your choice and complete the following two tasks:

1. Make the thematic map for the chosen topic, highlighting the STREAM knowledge for each domain.

2. Select relevant knowledge from the fields indicated in the map from the previous task and show how you would integrate it into a lesson plan. Explain how you would teach to 4th grade students the selected science topic and describe the lesson moments and how you would connect knowledge from the 6 domains using the STREAM approach.

Sampling

We used a convenience sample that ensured access to third-year students. Participants received a link to the online study scales through the Teams platform and their participation was voluntary, the study respecting the ethical standards specific to exploratory research. However, students who decided to participate in the study were rewarded with 1 point score to the final grade (for the Science Didactics course). Those who completed the scales agreed that the collected data would be used for research purposes,

preserving the anonymity and confidentiality of the data. Of 122 students invited to participate in the research, 113 agreed to participate and answered the scales (the response rate percentage was 92.62%), with no consequences for those who declined to participate.

Data analysis methods

Data were analyzed with the SPSS software. For the individual STREAM assessment, students had to complete two tasks, each worth 6 points. In the case of the first task *("To make the thematic map of the science topic highlighting the STREAM knowledge"*), it was observed how the students correctly identified the content of each STREAM domain for the theme they selected, being able to receive a maximum of 1 point for each domain and a total of 6 points for this task. In the case of the second task (*"Select the knowledge from the fields indicated in the map from the previous task and show how you would integrate it into a lesson plan"),* we assessed how students identified relationships and integrated the six domains, allocating a maximum point of 1 for each domain and a total of 6 points for this second task. In the case of the second task, we also aimed to see which are the areas between which the students identify the relationships most easily. Two experts were used to code the STREAM task and the inter-rated reliability coefficient was 0.849 ($p<0.001$) which indicates good reliability according to Koo and Li (2016).

Results

The indicators of descriptive statistics for metacognitive awareness and STREAM skills are presented in Table 1.

Table 1. Descriptive statistics Metacognition and STREAM

		METACOGNITION	STREAM
N	**Valid**	109	109
	Missing	0	0
Mean		3.87	7.20
Median		3.98	7.50
Mode		3.50	7.50
Std. Deviation		.648	1.30
Variance		.421	1.69
Skewness		-.786	-1.96
Std. Error of Skewness		.231	.231
Kurtosis		.374	7.49
Std. Error of Kurtosis		.459	.459
Minimum		2.00	.55
Maximum		4.99	10.00

The mean of metacognitive awareness in science is 3.87, which is quite high given that the maximum score that can be obtained is 5. Regarding the STREAM variable, the mean registers a noteworthy 7.20, with participants having the opportunity to earn a maximum of 12 points. The analysis of the skewness and kurtosis scores allows us to consider the data distribution as normal.

In the following tables (Table 2, Table 3, Table 4, and Table 5) we elaborate the descriptive statistical indicators for metacognition and STREAM according to age and the area of origin.

Table 2. METACOGNITION Descriptives

AGE		Statistic	Std. Error
20-25	**Mean**	**3.823**	.096
	Median	3.991	
	Variance	.470	
	Std. Deviation	.685	
26-30	**Mean**	**4.039**	.139
	Median	4.080	
	Variance	.329	
	Std. Deviation	.573	
31-35	**Mean**	**3.631**	.164
	Median	3.770	
	Variance	.462	
	Std. Deviation	.679	
36-40	**Mean**	**4.068**	.133
	Median	4.157	
	Variance	.215	
	Std. Deviation	.463	
41-45	**Mean**	**3.878**	.202
	Median	3.948	
	Variance	.451	
	Std. Deviation	.671	

According to Table 2, it seems that metacognition does not differ according to the participants' age, the metacognitive awareness scores being included among the values of 3.631 and 4.068. However, a means test must be performed to check if there are significant differences between the different age groups. The age differences do not seem to be significant for STREAM skills either (Table 3).

Table 3. STREAM Descriptives

AGE		Statistic	Std. Error
20-25	**Mean**	7.322	.171
	Median	7.500	
	Variance	1.470	
	Std. Deviation	1.212	
26-30	**Mean**	6.950	.467
	Median	7.200	
	Variance	3.718	
	Std. Deviation	1.928	
31-35	**Mean**	6.752	.277
	Median	6.800	
	Variance	1.307	
	Std. Deviation	1.143	
36-40	**Mean**	7.450	.288
	Median	7.600	
	Variance	.997	
	Std. Deviation	.998	
41-45	**Mean**	7.500	.309
	Median	7.900	
	Variance	1.051	
	Std. Deviation	1.025	

For STREAM skills, the means rage between 6.800 and 7.500 according to the age of prospective teachers. The lowest interval was identified for the age range of 31-35 years and the highest for 41-45 years.

An ANOVA test was applied to check whether there were significant differences between participants in metacognitive awareness and STREAM skills by age group. The results are presented in Table 4.

Table 4. ANOVA AGE VARIABLE

		Sum of Squares	df	Mean Square	F	Sig.
METACOGNITION	Between Groups	2.871	6	.478	1.147	.341
	Within Groups	42.546	102	.417		
	Total	45.416	108			
STREAM	Between Groups	8.748	6	1.458	.855	.531
	Within Groups	173.883	102	1.705		
	Total	182.631	108			

The results of the ANOVA test show no significant differences between the means for metacognitive awareness by age (p=0.341). The same insignificant results were found for STREAM skills, the level of significance being 0.531. It seems that neither metacognition nor STREAM significantly differ according to the participants' age.

To check if there is any significant relationship between metacognitive awareness and STREAM skills and if one variable changes in accordance with the other one, we used the Pearson correlation coefficient. The results of the correlational analysis are presented in Table 5.

Table 5. Correlations

		STREAM	METACOGNITION
STREAM	Pearson Correlation	1	.382**
	Sig. (2-tailed)		.000
	N	109	109
METACOGNITION	Pearson Correlation	.382**	1
	Sig. (2-tailed)	.000	
	N	109	109

**. Correlation is significant at the 0.01 level (2-tailed).

The results of the correlation analysis indicate a significant, medium, and positive correlation between the level of metacognitive awareness and STREAM skills, r (109) = .38, p<0.001. These results allow us to go further and check if metacognition might be a significant predictor for STREAM skills (Table 6, Table 7 and Table 8).

Table 6. Model Summary

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate
1	.382[a]	.146	.138	1.20724

a. Predictors: (Constant), METACOGNITION

Table 7. ANOVA[a]

Model		Sum of Squares	Df	Mean Square	F	Sig.
1	Regression	26.685	1	26.685	18.310	.000[b]
	Residual	155.945	107	1.457		
	Total	182.631	108			

a. Dependent Variable: STREAM
b. Predictors: (Constant), METACOGNITION

Table 8. Coefficients[a]

Model		Unstandardized Coefficients		Standardized Coefficients	t	Sig.
		B	Std. Error	Beta		
1	(Constant)	4.241	.703		6.030	.000
	METACOGNITION	.767	.179	.382	4.279	.000

a. Dependent Variable: STREAM

The correlation of metacognition with STREAM is 0.382, with an R^2 of 0.146, which means that metacognitive awareness accounted for 14.60% of the explained variability in the STREAM skills (Table 6). The regression model that was run has statistical significance with an F-statistic of 18.310 and a p-value less than 0.001 ($p<0.001$). Thus, the results show that there was a significant relationship between metacognitive awareness and STREAM skills ($t=4.279$, $p<0.001$), with the average level of the STREAM skills of 4.241 when the level of metacognition is zero. Each additional unit increase in metacognition is associated with an increase of 0.767 in the STREAM skills.

Conclusions and discussions

The paper showcases the reasons why metacognition and STREAM education are essential elements in today's informational society for both personal and professional development, highlighting the significance of integrating these concepts into science education. Also, it affirms the necessity to establish a relationship between these two fields, despite the lack of literature on this topic.

Both metacognitive awareness and STREAM education hold essential roles today, in both educational and professional background. Metacognition facilitates the selection and integration of relevant information from the multitude of information currently available, bringing its contribution to the vital lifelong learning requirements of most

professions. Research in the field of metacognition already has a long tradition, thus asserting its importance today. However, metacognition has not been studied in relation to STREAM education. STREAM education also facilitates the integration of knowledge from the six essential fields for the development of both educational and professional life today. Hence it is important to study both variables and explore the relationship between them. But studies addressing these two themes are almost non-existent. Thus, the present study is a pioneer in this direction.

Although the study acknowledges the absence of a substantial theoretical background to integrate metacognition and STREAM education, it emphasizes the potential for developing a coherent theoretical perspective based on these findings, the results representing a valuable starting point for further research and theoretical exploration in this area. Future research samples with different academic backgrounds and geographic areas need to be included in the study of this topic in order to increase the generalizability of the results, this being one of the limits of the present research. Another limit of the study is represented by the lack of a standardized instrument to assess the STREAM skills which could be translated and adapted cross-culturally.

By investigating the relationship between metacognition and STREAM knowledge in science education, the study signals the existence of a significant relationship between the two variables-established through data analysis. The paper also stresses on the vital role that metacognition plays in predicting STREAM knowledge in science education. This implies that individuals who possess strong metacognitive abilities are more likely to excel in integrating STREAM knowledge in science-related subjects.

To sum up, the present study contributes to the existing literature by addressing the scarcity of research on the relationship between metacognition and STREAM education in science. It emphasizes the importance of exploring and understanding this connection, the findings of this study having practical implications for education, particularly for future primary and preschool teachers. Nevertheless, understanding the relationship between metacognition and STREAM knowledge can help educators design more effective teaching strategies and curriculum to enhance students' learning outcomes.

The study's results provide relevant insights into how to analyze and incorporate metacognition and STREAM education into a consistent theoretical perspective, specifically in the context of science education. This could lead to improved approaches for teaching and learning in science-related fields. Moreover, the development of metacognitive and STREAM

skills may have a positive impact on the international tests results of the Programme for International Student Assessment and Trends in International Mathematics and Science Study, and on forming the workforce in the STREAM-related fields. The demand for STEM/ STREAM professionals is increasing worldwide as there are estimated about 7 million job vacancies for 2025 timeline (Roungos et al., 2020). Consequently, ensuring the existence of well-prepared individuals able to fulfil the metacognitive and STREAM skills requirements of STREAM-related careers is associated with economic growth (Freeman, 2006). STEM/ STREAM education develops at a global level being related to the OECD policies on worldwide instruction (Pugliese & Santos, 2022).

In conclusion, the paper highlights the importance of metacognition and STREAM education while providing evidence for a significant relationship between the two. It emphasizes the potential of metacognition as a predictor of STREAM knowledge and emphasizes the value of this research in contributing to the development of a theoretical perspective in this area. These conclusions also have implications for education and call for further research to expand the understanding in this field.

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