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ROMANIAN TEACHERS' READINESS TO IMPLEMENT STEM EDUCATION WITH PRESCHOOL AND ELEMENTARY SCHOOL STUDENTS

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Abstract: STEM education is increasingly capturing the attention of researchers, practitioners and stakeholders interested in education. Its importance in the current and future workforce is undeniable and formal instruction in this field is a must nowadays. STEM teaching can be offered to children from kindergarten to high school. Therefore, teacher training institutions should consider introducing STEM as a separate discipline in their training curriculum, because teachers might not be ready to teach this topic. To establish the readiness of STEM teaching in Romanian preschool and elementary school institutions, the present study analyses teachers' attitudes and readiness to teach STEM to preschool and elementary school students. The self-reported scale completed by 129 in-service teachers shows that teachers enjoy teaching STEM and see its value for students' learning and their own professional growth embrace the responsibility for making STEM meaningful, engaging, and collaborative for students. However, they encounter significant implementation barriers like time and workload constraints, difficulties in managing diverse student levels and in applying STEM to real-life contexts, and the inconsistent use of official resources/modules.

Key words: STEM education, perceived self-efficacy, preschool and elementary school prospective teachers

1. Introduction

STEM education has gained momentum, expanding both in different countries and at different levels of education. The STEM acronym is now widely known, and the integration of science, technology, engineering and mathematics does not seem to be a challenge for most teachers nowadays. Research shows that STEM education is widely recognized as a subject area officially integrated into the curricula of school across different countries. The need to integrate the STEM approach into regular education is no longer questioned these days.

STEM education has developed so rapidly that it has begun to encompass other fields besides the initial four, such as arts (STEAM) and robotics (STREAM). Although at a theoretical level this development has been well received by theorists from various fields, in practice it is difficult to keep up with the latest theoretical discoveries. Teachers and other educational practitioners might need support for the implementation of the latest theoretical discoveries within the educational field. Research emphasizes that one challenge in implementing STEM education is the gap between theory and practice in the STEM curriculum (Ihalon et al., 2025) and knowledge gaps or low confidence among teachers in incorporating concepts from disciplines in which they do not hold a degree (Asli & Zsoldos-Marchis, 2021). A bibliometric analysis conducted by Irwanto and Hutahaean (2025) shows that during 2002 and 2020 a number of 1282 articles on STEM education have been published.

Several theoretical perspectives regarding STEM education have been developed over the past years.

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Some approaches promote a more disciplinary or disconnected integration of STEM disciplines while others build up a transdisciplinary approach (Wieselmann et al., 2025). Proposals related to the development of a STEM curriculum also vary according to these theoretical perspectives. Fogarty (1991) proposes a model that includes ten different approaches of the integrated curriculum, from the fragmented curriculum to the networked curriculum. In the initial stages, the integrated curriculum is focused on single disciplines and can take the forms of fragmented curriculum, connected curriculum or nested curriculum. The integration across several disciplines has five models according to Fogarty: sequenced, shared, webbed, threatened, and integrated. The last models of the integrated curriculum involve the immersed approach and the networked one (Fogarty, 1991).

Another perspective on how to integrate STEM in the curriculum is the one developed by Davison and colleagues (1995). Their model includes five perspectives of discipline integration. The first, discipline-specific integration, involves approaching specific topics of each discipline within each discipline itself. For example, exploring a specific science topic using mathematical ideas but without crossing discipline boundaries. The second perspective (content-specific integration) is focused on integrating specific content of different disciplines (such as integrating specific math concepts withing science lessons) while the third one involves process integration, which means merging methods from different disciplines (such as scientific data collection and mathematical statistical analysis). Methodological integration, the fourth perspective, involves using similar teaching and learning methods in the teaching of different disciplines (learning cycles or discovery-based learning strategies). The last perspective, thematic integration, involves organizing lessons around specific themes and real-world problems than around specific subjects.

Although the field has experienced accelerated development and both theorists and practitioners in the educational field are familiar with this concept, integrating it into the daily school practice is not necessarily something easy to achieve. Research indicates that although STEM is widely known, teachers might encounter some difficulties in implementing it into their daily teaching. But the need to integrate STEM into mainstream education is not questionable anymore nowadays. Although technological and digital tools are highly used in Romanian schools (Mara et al., 2024), pre-service preschool and primary school teachers have scarce experience in STEM instruction (Bálint-Svella & Zsoldos-Marchiș, 2022). Therefore, several researchers have focused their attention on the STEM competencies held by teachers and on the impediments to the implementation and development of STEM education. However, what is certainly sure is that prospective pre-school and primary school teachers must be instructed in teaching STEM (Ciascai & Zsoldos-Marchis, 2029; Wieselmann et al., 2025) and schools should have teachers specialized on STEM education to be mentor for their colleagues (Zsoldos-Marchis & Ciascai, 2019). Also, books and guides giving concrete examples of implementing STEM education, such as the volume edited by Șuteu et al. (2024b) are essential to familiarize pre-service and in-service teachers with this approach.

How well-prepared teachers consider themselves implementing STEM education, their attitudes and perceptions toward this field and their abilities to teach in this field influences on a certain extent the level of preparation of students in the STEM field. Literature emphasizes three types of readiness to implement STEM instruction in classroom: cognitive readiness, affective readiness, and behavioral readiness (Abdullah et al., 2017; O'Neil et al., 2014; Papagiannopoulou et al., 2023). Crameri and colleagues (2019) consider cognitive readiness as an essential concept able to predict students' performance in real-world environments. The effective use of cognitive dimensions like adaptability, effective communication, creative and critical thinking, decision-making, metacognitive strategies, pattern recognition, problem-solving abilities, situational awareness, team cohesion, and interpersonal competence can be included in the concept of cognitive readiness (Papagiannopoulou et al., 2023; Șuteu et. al, 2024a). The affective readiness is generally categorized into three domains: positive, negative, and neutral. Positive affect encompasses emotions and moods such as joy and enthusiasm, while negative affect includes adverse states such as boredom, disappointment, stress, and anxiety. Neutral affect, by contrast, denotes the absence of an emotional response to a given situation at a particular moment (Papagiannopoulou et al., 2023). Behavioral readiness is closely associated with teachers' responses to change and is defined as an attitude that reflects affective reactivity toward transformation, which subsequently manifests in observable behaviors. Teachers who demonstrate expertise and competence in adopting new practices are considered to possess a high and positive degree of behavioral readiness (Abdullah et al., 2017).

The systematic review conducted by Yim and colleagues (2024) shows that implementing STEAM education in primary schools improves students' attitudes toward STEAM, and their knowledge and skills in this domain. Implementing STEAM-related programs is shown to increase linguistic and mathematical competencies of primary school students, especially in girls and in students who have a history of immigration (Duo-Terron et al., 2022). However, research indicates that teachers might not feel confident in teaching STEAM, having a low self-efficacy level (Bagiati & Evangelou, 2015; Wei & Maat, 2020). However, more studies are needed in this direction since it seems that in the case of STEM teaching, self-efficacy is more important than past performance measured through tests and assignments (Escobar, 2023). This study addresses the issue of teachers' readiness to implement STEM subjects in primary schools. Readiness to implement STEM in primary schools

2. Methodology

2.1. Participants

Data were gathered from 129 in-service teachers enrolled in a professional conversion program to become primary and preschool teachers. The age range of the participants varied from 20 to 54 years. Only five teachers were men, the rest were women. Participants were all practicing pre-university teachers. This was a requirement for attending the training program and getting the needed credits to become a preschool and primary school teacher. Thus, students who participated in the study already had a teaching certificate for either secondary or high school levels.

2.2 Sampling

We used the convenient sampling method for choosing the in-service teachers enrolled in a preschool and elementary school training program as participants for our study. All students enrolled in the program were invited to attend the research during one face-to-face meeting and afterwards they received an online link to complete the self-assessment instruments.

2.3 Scale

The scale used to measure teachers' readiness to apply STEM education in their daily teaching is a self-reported one. Abdullah and colleagues (2017) developed the scale to assess teachers' readiness to implement STEM. Their scale measures readiness from three dimensions: cognitive, affective, and behavioral. The scale used in this study has 28 items measured on a five-point Likert scale (strongly disagree – strongly agree). The first nine items measure the cognitive aspects of the readiness to teach STEM, the following eleven statements assess the affective dimension of STEM teaching readiness, and the last eight are focused on the behavioral aspects. The whole scale has an alpha Cronbach of 0.965. The reliability coefficient for the first dimension (affective aspects) is 0.931, while the second and the third dimensions have reliability coefficients of 0.948 and 0.898. Papagiannopoulou and colleagues (2023) reported good psychometric properties of a similar scale.

2.4 Procedure

The invitation to voluntarily participate in the research was sent via an online teaching platform where participants were enrolled. The self-assessment tool was available online for two months. Responses were automatically recorded in the Google document created for this study.

3. Results

3.1 Demographic data

The demographic data of our participants varies among each variable (Table 1). The distribution of participants by age is as follows: 26.4% fall within the age range of 20-25 years, 35.7% between 26-34 years, 25.6% are 35-44 years and 12.4% fall within the age range of 45-54 years. Regarding the teaching experience of participants, most fall in the category of "less than 5 years" of experience (58.9%). 10% of participants have between 5 and 15 years of teaching experience, 29.5% between 16-

25 years and 1.6% have more than 26 years of teaching experience. More than 50% of teachers had only a high school diploma at the time of the research (66.7%). A bachelor's degree was owned by a percentage of 32.6% and one participant had an M.A. degree.

Table 1. *Demographic data*

Category	Subcategory	Percentage
Age (years)	20–25	26.4%
	26–34	35.7%
	35–44	25.6%
	45–54	12.4%
Teaching Experience	< 5 years	58.9%
	5–15 years	10.0%
	16–25 years	29.5%
	26+ years	1.6%
Education Level	High school diploma	66.7%
	Bachelor's degree	32.6%
	Master's degree (M.A.)	0.7%

3.2 Teachers' level of readiness to teach STEM

Teachers have above average levels of STEM teaching readiness. The mean for the cognitive dimension is 4.077, which indicates a high level of STEM teaching readiness. The affective dimension has a level of 3.859, an above average level of the readiness to teach STEM. The last dimension, the behavior one, has a mean of 3.882.

Teachers' demographic characteristics do not influence their level of readiness to teach STEM. Statistical analysis indicates that neither age, teaching experience, level of education or teaching have a significant impact on teachers' readiness to implement STEM. These results are valuable and inform us that a program for increasing teachers' readiness to implement STEM can be designed and implemented with teachers of different ages, different teaching experience and different teaching levels.

Table 2 illustrates the readiness to teach STEM from a cognitive perspective. The percentage of teachers who have a low level of cognitive readiness to teach STEM is extremely small. Most teachers understand the objectives of implementing STEM education drawn up in the curriculum. Moreover, most of them know their role in implementing STEM education at school, use STEM practices to solve problems in the context of daily life, and collaborate with other teachers to improve STEM education through multimodal learning. A detailed analysis of these results is given below the table.

Table 2. *Teachers' level of readiness to teach STEM from the cognitive aspect*

Item	Strongly disagree	Disagree	Neither agree nor disagree	Agree	Strongly agree
1. I understand the objectives of implementing STEM education drawn up in the curricum	0	4.7	24.8	37.2	33.3
2. I understand the teachers' role in implementing STEM education at school	0	3.9	24	36.4	35.7
3. I implement the STEM approach in my teaching which involves applying STEM practices to solve problems in the context of daily life	1.6	12.4	29.5	33.3	23.3
4. I am responsible in ensuring that my students are able to explore their surroundings by	0	5.4	18.6	32.6	43.4

solving problems that are related to the real world in the effort to instil STEM practices					
5. I need to discuss with other mathematics teachers to further improve my teaching quality of STEM education using multimodal learning	0	2.3	20.2	26.4	51.2
6. I am responsible for ensuring that the process of teaching and learning STEM education that is student centred is able to produce meaningful learning experience	0	1.6	18.6	30.2	49.6
7. I am responsible for ensuring that the process of teaching and learning STEM education that is student centred is able to produce a fun learning experience	0	1.6	17.8	31	49.6
8. I need to spend a lot of time searching for effective ideas before implementing teaching and learning of STEM education integration in the classroom	0	5.4	20.2	31.8	42.6
9. I refer to the STEM education module to ensure that I have a clear understanding in the implementation of this approach according to the procedures and requirements of Ministry of Education	0	5.4	31.8	26.4	36.4

The percentage of those who disagree ("Disagree" and "Strongly Disagree") is very low (below 15% for all items, sometimes even 0%). This shows a clearly positive trend, with a favorable attitude of teachers towards STEM implementation.

Understanding the goals and role of the teacher (Items 1–2)

For the item "I understand the goals of STEM", a percentage of 70.5% agreed and strongly agreed with the statement while for the statement "I understand the role of the teacher" the agreement and strongly agreement percentages were of 72.1%. It seems that most teachers report having a good conceptual understanding of STEM and their role, but there is a quarter (~24%) who remain neutral. It is possible that they have limited or uncertain knowledge.

Practical implementation of STEM (Items 3, 8, and 9)

For the third item, (I apply STEM in teaching in real contexts), only 56.6% agree/strongly agree, 29.5% neutral and 14% disagree. Item 3 has the most balanced distribution, with more neutral and negative responses compared to the rest. The following item, the 8th one (I look for ideas for implementation), has 74.4% agree and strongly agree, but 20.2% neutral, which shows that teachers perceive practical difficulties and the need for additional time. For the statement *I refer to the official STEM module*, 62.8% agree and strongly agree with it, but 31.8% are neutral, which suggests that not everyone consistently uses official resources, possibly due to lack of access or familiarity. It seems that there is a difference between theoretical knowledge (high) and practical application (more modest, less consistent).

Teacher Responsibility and Student Experience (Items 4, 6, and 7)

Teachers consider that it is their responsibility to ensure that students have opportunities for exploring reality and having enjoyable and meaningful experiences. Thus, 76% agreed and strongly agreed that it is the teacher's responsibility to create opportunities for students to explore reality. High percentages also agreed and strongly agreed that teachers have the responsibility to censure that students have meaningful (79.8%) and enjoyable (80.6%) learning experiences.

According to the results presented above, we can assert that teachers have a strong belief in their responsibility to create meaningful and engaging learning experiences. Almost no one rejects this idea.

Collaboration between teachers (Item 5)

77.6% agreed and strongly agreed they need to collaborate with other teachers to be able to offer a quality STEM education. Teachers feel the need for collaboration and support among colleagues, which suggests openness to professional development.

Teachers have a high level of awareness and positive attitude towards STEM (understood role, accepted responsibility). However, we identified a knowledge-practice gap: difficulties arise in concrete implementation, which indicates the need for practical training and additional resources. We also observed a positive trend of uniformity: almost no one rejects STEM → either there is a real consensus, or a social desirability bias intervenes (teachers respond "as they should").

The survey results show that teachers have a solid understanding of STEM objectives and their role in implementation (over 70% agreeing). In contrast, the concrete application of STEM practices in teaching is lower, with only 56.6% stating that they use them frequently. This gap between knowledge and application indicates the need for practical training programs and access to resources. In addition, respondents emphasize collaboration among teachers (77.6% agreeing), which suggests that STEM implementation strategies should include professional community activities and the exchange of best practices.

Teachers seem to enjoy and to be happy to implement STEM education in classroom using students' strengths and weaknesses. They also consider STEM an important tool that improves communication between students and teachers and allows teachers to use it to connect school to real-world contexts. An encouraging result of the study shows that teachers do not feel any stress or burden to teach STEM. In fact, they feel at ease for being able to implement the STEM education approach in a way that is systematic and organized (65.9%), are excited to implement STEM education approach in classrooms as it enables them to understand students' grasp of knowledge (73.6%) and they do not feel disappointed with the implementation of STEM education approach although it makes it harder for them to finish teaching the syllabus (59.7%).

Table 3. *Teachers' level of readiness to teach STEM from the affective aspect*

Item	Strongly disagree	Disagree	Neither agree nor disagree	Agree	Strongly agree
1. I enjoy implementing STEM education approach in teaching and learning in the classroom.	0	4.7	22.5	43.4	29.5
2. I am happy with the implementation of STEM education approach as it is able to help me identify students' strengths.	0	3.9	22.5	38	35.7
3. I am happy with the implementation of STEM education approach as it is able to help me identify students' weaknesses.	0	4.7	20.2	46.5	28.7
4. I am satisfied with the implementation of STEM education approach as it is able to increase my two-way communication with students.	0	3.9	23.3	41.9	31
5. I feel at ease for being able to implement the STEM education approach in a way that is systematic and organized.	0	7	27.1	38.8	27.1
6. I am excited with the implementation of STEM education approach in classrooms as it enables me to understand students' grasp of knowledge.	0	3.1	23.3	42.6	31
7. I do not feel burdened by the many elements contained in STEM education that need to be related to the realworld context.	0.8	8.5	36.4	27.9	26.4

8. I do not feel disappointed with the implementation of STEM education approach although it makes it harder for me to finish teaching the syllabus.	0.8	9.3	30.2	33.3	26.4
9. The differences in students' level of mastery do not make it difficult for me to implement STEM education approach in the classroom.	2.3	6.2	32.6	31.8	27.1
10. I do not find difficulties in implementing STEM education.	2.3	10.9	34.9	31.8	20.2
11. I do not feel pressured with the increased work burden.	2.3	7.8	27.9	34.1	27.9

Across all items, agree and strongly agree responses are consistently higher than Disagree categories. This suggests that teachers see value and enjoyment in STEM education, especially in improving teaching-learning interactions.

Communication and understanding (Items 4 and 6)

72.9% of teachers agreed that STEM allows them a two-way communication with students and 73.6% consider that STEM allows them to understand students' knowledge. These indicates that STEM is perceived to enhance student–teacher engagement and comprehension.

Systematic Implementation Challenges (Item 5)

Only 65.9% agreed and strongly agreed that they can apply STEM in a systematic and organized way, with 27.1% neutral and 7% disagreeing. This suggests that systematic implementation may still be a challenge.

Burden & Challenges (Items 7, 8, 10 and 11).

Regarding the burden to teaching STEM and relating it to real-world settings, 54.3% answered agree and strongly agree, while 36.4% neutral and 9.3% negative. More than half of the participants are not disappointed to teach STEM despite syllabus pressure (59.7%), while 30.2% are neutral and 10.1% negative. Teachers seem to have some difficulties in implementing STEM. Although just a slight percentage above average stated they do not have difficulties in implementing STEM, 34.9% were neutral and 13.2% negative. Most teachers are pressured by the workload related to STEM teaching (62%), although there is a significant percentage who associate STEM with the pressure of workload (38%). These items reveal that while teachers see benefits, they also feel workload pressure, time constraints, and practical challenges.

Neutral Tendencies

A relatively high proportion of neutral responses (20–36%) appear across items, especially in systematic implementation (27.1%), real-world connections (36.4%), different student levels (Item 9 – 32.6%) and implementation difficulties (34.9%). This indicates that there is some uncertainty or ambivalence among teachers, possibly due to lack of training, resources, or confidence.

These results indicate that teachers enjoy STEM, see it as beneficial for students and reflective for themselves, and believe it fosters better communication. They also have some concerns and there are issues arise in workload, syllabus completion, adapting to different student mastery levels, and systematic implementation.

Practical implications: The data suggest that to transform enthusiasm into sustainable implementation, teachers need additional training, curriculum-appropriate resources, and support mechanisms for differentiation and time management.

Table 4. *Teachers' level of readiness to teach STEM from the behavior aspect*

Item	Strongly disagree	Disagree	Neither agree nor disagree	Agree	Strongly agree
1. STEM education allows me to conduct activities by preparing materials that are able to attract the attention of students in the classroom based on their capabilities.	0	4.7	24	28.7	42.6
2. I am prepared to attend STEM education enhancement courses to enhance my skills.	0	0.8	17.8	27.1	54.3
3. I am prepared to attend STEM education enhancement courses to enhance my knowledge.	0	3.9	15.5	23.3	57.4
4. I always analyse students' achievement in STEM education for further actions.	0	6.2	30.2	29.5	34.1
5. I have to work overtime to monitor students' progress in the classroom.	0.8	11.6	29.5	34.9	23.3
6. I do not find difficulties in controlling students during the teaching and learning of STEM education in the classroom.	0	13.2	36.4	31.8	18.6
7. I have enough time to implement STEM education although I need to cover many syllabuses.	3.1	17.1	34.1	29.5	16.3
8. I do rigorous preparations before implementing STEM education approach in the classroom.	1.6	9.3	31	30.2	27.9

Positive Aspects of STEM Implementation (Item 1, 2 and 3)

71% of teachers believe that STEM education allows them to conduct activities based on materials adapted to the students' needs. This shows that teachers feel that STEM education engages students effectively through well-prepared materials. Although teachers feel that they are prepared to teach STEM and they enjoy it, most of them agree (above 80%) that they would attend specific STEM courses to improve their knowledge and skills in this field. This shows teachers' willingness for professional development in the STEM field.

Student Monitoring and Assessment (Item 4 and 5)

While many teachers monitor achievement (63.3%), a large neutral group (30.20) suggests inconsistent or irregular assessment practices. Furthermore, with 58.2% agreement, 29.5% neutral, 12.4% disagreement, some teachers acknowledge that monitoring adds extra workload while others remain neutral.

Classroom Management & Time Constraints (Item 6 and 7)

Classroom management remains a challenge for many teachers during STEM activities (50.4% agree and strongly agree, 36.4% neutral and 13.2% disagree). In addition, the time constraint is one of the biggest barriers in STEM education implementation (34.1% neutral and 20.2% stating they do not have enough time).

Preparation Before STEM Implementation (Item 8)

Participants agreed that they rigorously prepare themselves before implementing STEM education in classroom (58.1%). Though, a significant neutral portion (31%) may reflect variability in teaching practices or lack of standardized guidelines.

4. Discussion and conclusions

The results presented above indicate that most teachers enjoy and value STEM education. Many agree that it engages students and sees STEM as beneficial for students and themselves (e.g., identifying students' strengths, reflecting on their own teaching weaknesses, improving communication). This shows a fundamentally positive mindset toward STEM adoption.

Teachers show very high readiness for professional development. Over 80% are positive about attending STEM enhancement courses and have a strong willingness to collaborate with peers. Teachers are motivated lifelong learners, seeing STEM as an opportunity to improve skills, knowledge, and teaching quality. This result is significant since research indicates that STEM training programs improve personal and professional development of teachers (Asli & Zsoldos-Marchis, 2023; Papagiannopoulou & Vaiopoulou, 2024).

They also feel a strong sense of responsibility to make STEM meaningful and enjoyable and around 80% positive for ensuring student-centered, fun, and meaningful learning experiences and focus on real-world problem-solving. Teachers align well with the core philosophy of STEM — inquiry, exploration, and engagement.

Despite positive attitudes, several practical challenges appear consistently. One of these is the time constraints and workload. Many feel burdened by syllabus demands and agree that monitoring student progress often requires overtime. Teachers admit they need a lot of time to prepare for lessons. Only about 50% are positive about finding no difficulty controlling students during STEM activities, which indicates challenges in managing diverse learners and group activities.

As the general conclusion, teachers enjoy STEM and see its value for students' learning and their own professional growth, strongly embrace responsibility for making STEM meaningful, engaging, and collaborative, and show high motivation for training and teamwork to improve their STEM practices. However, they face significant implementation barriers like time and workload constraints, difficulty managing diverse student levels, challenges applying STEM to real-life contexts, inconsistent use of official resources/modules, and a notable portion still uncertain about objectives and roles.

Following the results of this study, several recommendations were formulated for schools and policymakers regarding strengthening STEM implementation:

1. Provide more structured training focused on *practical strategies for real-world STEM integration*.
2. Allocate time and reduce workload pressure by aligning STEM with the syllabus.
3. Offer ready-to-use teaching resources and lesson modules to reduce preparation burden.
4. Encourage peer collaboration networks for sharing ideas and best practices.
5. Strengthening classroom management support through training in active learning and differentiated instruction.

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