European Journal of Science and Mathematics Education, 2025, **13**(2), 119-136
ISSN: 2301-251X (Online)

Research Article

Greek primary teachers' views about STEM education

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Citation: Mandrikas, A., & Stefanidou, C. (2025). Greek primary teachers' views about STEM education. *European Journal of Science and Mathematics Education, 13*(2), 119-136. https://doi.org/10.30935/scimath/16162

ARTICLE INFO

Received: 17 Sep 2024

Accepted: 11 Feb 2025

ABSTRACT

In this paper, primary teachers' views about STEM education and the conditions of its introduction to primary education are investigated. The results came from 114 questionnaires and 27 structured primary teachers' interviews. STEM is clearly perceived as an interdisciplinary subject with many advantages, related to the cultivation of students' scientific thinking and their social skills. Primary teachers support its introduction to primary education, but they believe that it needs better preparation and design. For the successful introduction of the STEM in primary education teachers' training, the provision of infrastructure and equipment and more time in the timetable is needed. Finally, teachers raise the issue of the need for increased accessibility to STEM education as a means of facing gender, racial and social inequalities. In this line, they demand financial support from the state, to strengthen STEM education in all public schools and not only in well-paid schools.

Keywords: STEM education, primary teachers, critical education

INTRODUCTION

It is widely accepted that students who practice "inquiry" learn to solve real-life problems, which includes the development of creative reasoning, critical thinking, collaboration, communication and digital literacy, thus in the long term they are prepared for everyday life (Crawford & Capps, 2018; Tytler & White, 2019).

Nowadays, the term "inquiry" has gradually been replaced by eight scientific and engineering practices, published in the USA framework for K-12 science education (Garcia-Carmona, 2020; National Research Council, 2012) and specifically in the next generation science standards (National Research Council, 2013). These practices are for students to

(1) ask questions and define problems,
(2) plan and carry out investigations,
(3) develop and use models,
(4) analyze and interpret data,
(5) use mathematics,
(6) construct explanations,
(7) engage in argument from evidence, and
(8) evaluate and communicate information.

Concerning the debate between "practices" and "skills" the framework for K-12 science education makes clear that the term "practices" in scientific investigation includes not only "skills" but also "knowledge" (National Research Council, 2012, p. 30). In addition, "scientific practices" have been associated in the literature of science education with problem-based approach (Kang et al., 2019; Roberts et al., 2018), authentic experience

(Crippen & Antonenko, 2018; Stroupe, 2015), real-world issues (Campbell & Oh, 2015; Martín-Páez et al., 2019), hands-on activities (Anand & Dogan, 2021; Kang et al., 2019). Last but not least, active participation through "scientific practices" has been found to reinforce students' critical thinking (Crawford & Capps, 2018; Kelley & Knowles, 2016; Margot & Kettler, 2019).

In the last two decades STEM education has been proposed as an educational reform of science education worldwide (Bybee, 2013; Honey et al., 2014; National Research Council, 2011; Sanders, 2009). STEM education intends to connect school learning to everyday life through familiarity with real-life problems (Du Plessis, 2018; Hathcock et al., 2014). Thus, the students of the next generations should be prepared to solve real-world problems by applying interdisciplinary subjects, by implementing experiential activities and by developing critical thinking, collaboration, and creativity (Shernoff et al., 2017) as well as knowledge, reasoning, and argumentation (Mandrikas et al., 2023; Wilson et al., 2009).

LITERATURE REVIEW

The literature on STEM education has become very rich over the last two decades. Some researchers have recorded students' views about STEM education. In the USA, after participating in a summer STEM program based on hands-on activities, K-5 and K-8 students stated that they enjoyed an in-depth authentic learning experience, gained an understanding of many science concepts away from "boring" school settings, agreeably engaged in STEM activities, and extended their knowledge in science through experimentation (Roberts et al., 2018). Lamb et al. (2015) implemented for three years a STEM program in 254 primary students and recorded their improvement in self-efficacy, interest, spatial visualization, mental rotation and attitudes toward science. In another research, a STEM program has been used as a tool for critical thinking development in contrast with Artificial Intelligence (AI) and led high school students to a broader understanding of potential STEM careers by broadening their horizons and enabling them to envision professional pathways (Yoon & Ryu, 2024). In Turkey, Karakaya et al. (2020) recorded the views about STEM activities of 27 middle school students after participating in a 6-week STEM-oriented program. Students recognized and emphasized the importance of teamwork, the contribution of STEM activities to develop and apply knowledge of the separate subjects, the connection of STEM with daily life, and the possibility of a future career related to STEM. As main problems they referred to the shortage of time for the activities and the lack of materials.

In Greece, Stefanidou et al. (2023) recorded 350 primary students' views on STEM education with no previous experience in STEM activities. Most students responded that they were "very good" at science and mathematics and "good" at engineering and technology, but they were not sure to follow such career after finishing school. In another research, STEM education was used as a learning tool for teaching natural disasters in primary education through a three-month educational program in primary education (Mereli et al., 2023).

Several studies recorded teachers' views on integrated STEM education in schools. For example, Shernoff et al. (2017) interviewed 22 K-12 teachers and 4 administrators, in order to map the challenges and obstacles in developing and implementing integrated STEM curricula. They found that many teachers are interested in such kind of science curriculum, but they declared "not well prepared" to implement it. El-Deghaidy et al. (2017) interviewed in focus groups 21 science middle school teachers in Saudi Arabia, in order to investigate their views on STEM education and the factors that facilitate or hinder them to enact such kind of pedagogical activities. "Time, resources and lack of teachers' preparedness … were mentioned as external factors that could hinder the implementation of STEM in class. Teachers felt that they had internal barriers to using and enacting STEM practices in the class" (El-Deghaidy et al., 2017, p. 2473).

Numerous studies recorded teachers' views about or implementing STEM activities in class. In the USA, a sample of 123 primary and middle school teachers attended a 4-days summer STEM program and completed both pre and post questionnaires prepared by the researchers (Nadelson et al., 2012). The participants did not have any experience in STEM activities, but they were willing to participate in a professional learning community that would likely continue to support their STEM activities in school. Teachers' answers after attending this summer STEM program proved their notable positive shift in pedagogical contentment, in STEM teaching efficacy, in teaching by inquiry, in the conceptualization of content knowledge, in peer and team collaboration, in STEM definition, and in motivation for teaching STEM. In Spain, Toma and Greca (2018) after implementing an integrated STEM project based on hands-on activities in K-4 students recorded students and teachers' attitudes toward science. Questionnaires and interviews revealed positive attitudes for both students and teachers and favorable reception of STEM approach. However, teachers were more reluctant about STEM education and asked for more guided instructions, textbooks with laboratory activities, training, mentoring programs, and community of practice among peers and administrators. In Turkey, a case study based on four secondary teachers' interviews showed that STEM education connects students with everyday life, reinforces active learning, and increases students' self-confidence despite the lack of material or infrastructure (Bal & Bedir, 2021). In Thailand, views of 120 primary teachers on STEM education have been investigated by a closed-ended questionnaire (Nuangchalerm, 2018). The highest positive acceptance rates gathered the pre-determined statements about the connection of STEM with analytical thinking and problem-solving, students' active engagement and 21st century learning skills.

Similar findings have been recorded in two recent studies in Greece. Samara and Kotsis (2025) tried to investigate primary teachers' attitudes towards STEM and found that despite their previous training in STEM education only a few of them implemented corresponding STEM programs in school. For this purpose, primary teachers require continuous professional development, technical support, professional learning communities or networks and also ongoing evaluation and feedback mechanisms (Samara & Kotsis, 2025). In another research concerning pre-service teachers, it was found that the incorporation of educational robotics in STEM education requires teachers' training, curriculum reform, requisite resources and more time for allowing students to evolve into proactive citizens of 21st century (Gavrilas & Kotsis, 2024).

Teachers' beliefs and perceptions on STEM implementation in class have been investigated by many researchers through theoretical investigations and conceptual analyses. Margot and Kettler (2019) have made a systematic literature review of teachers' perceptions on STEM integration and education by analyzing 25 articles written between 2000 and 2016 in the field. Margot and Kettler (2019) support that "STEM in education is both a curriculum and pedagogy" (p. 2). This curriculum concludes "cross-curricular real-world challenges to solve" (Margot & Kettler, 2019, p. 3) providing opportunities for in-depth problem solving. STEM pedagogy is based on students' collaboration, support among peer teachers, interdisciplinary approach, questioning and reasoning. School teachers believe that for successful implementation of STEM education at all grades "collaboration with peers, quality curriculum, district support, prior experiences, and effective professional development" are recommended (Margot & Kettler, 2019, p. 1).

In a similar research Martín-Páez et al. (2019) reviewed 27 papers published between 2013-2018 in the database of the main Web of Science collection. These papers were selected among 312 papers with concrete criteria and used to refine terminology about STEM education, STEM teaching, STEM learning and STEM literacy. As a result, a lack of definition of terms, different combinations between disciplines of the acronym and the possible adoption of a dominant role for one of them, the diverse way in which these disciplines are integrated, lack of description of the content, a variety of benefits, and a series of key aspects "that should be considered when designing and implementing a STEM-focused educational intervention" (Martín-Páez et al., 2019, p. 813) have been analytically discussed. As useful teaching implications, the researchers suggest careful and defined use of terms so as to be clear the STEM perspective adopted and the benefits of each STEM intervention to be explicitly referred.

Concerning critical engagement with STEM practices, there is a shortage of support for critical reflective practice. Both formal and informal science education is marked by gender, racial/ethnic and social inequalities (Archer et al., 2024; Dawson, 2019; Garibay, 2015). However, many researchers maintain that STEM education should help students understand and act towards significant social issues, like structural inequities, social responsibility, social justice, civic engagement, democratic society (Amadei & Sandekian, 2010; Baillie et al., 2011; Calabrese Barton et al., 2003). Galamba and Gandolfi's (2023) recent edition aims at supporting school science teachers in understanding what critical pedagogy is and at giving insights into how it can be implemented, in diverse ways, in their science lessons.

In Greece, STEM education was introduced in the curriculum of compulsory education (primary and lower secondary education) as part of a new institution called "skills workshops" for the first time during the school year 2021-2022. Teachers at all grades should implement a STEM program of their choice for 5-7 weeks (1 hour per week) at grades Kindergarten, K-1, K-4, K-5, K-7, and K-8. This introduction was accompanied by online training seminars for teachers organized by the Institute of Educational Policy on voluntarily basis. Unfortunately, it was not accompanied by the provision of educational material and an increase in school funding. These benefits should be taken for granted by the Ministry of Education, given that public education has been significantly understaffed and underfunded over the past fifteen years. At the same time, Greece, along with other countries, was experiencing a multi-year economic and social crisis followed by a health crisis.

Although there is a lot of literature that investigates STEM education, there is limited literature on primary teachers' views on STEM introduction in primary education. In this line, this paper explores Greek primary teachers' views on STEM education and the appropriate conditions of its introduction in primary education.

METHODOLOGY

Research Question

The research questions of the present study were as follows:

1. What are Greek primary teachers' views towards STEM education?
2. Under which circumstances could STEM education effectively implemented in primary education?

Sample

The sample of the present study consists of 114 primary teachers, 23 male and 91 female, who voluntarily participated in the research. These teachers served in public schools in Attica (Greece) and they came from different social and economic background. Almost half of them (46%) had a master's degree in education and 6% had a PhD in education. Concerning their age, 53% were over 50 years old, 41% were between 30 and 50 years old and 6% were younger than 30 years old. Accordingly, 59% had teaching experience over 20 years, 30% between 11-20 years, 7% between 3-10 years and 4% had teaching experience less than 3 years.

According to the national curriculum, primary teachers in Greece are required to teach science and mathematics among other subjects (language, history, etc.), which do not include technology and engineering.

Data Collection

Data were collected from March to May 2022 through two research tools. First, a questionnaire consisting of 26 Likert scale closed-ended questions and 4 open-ended questions was created and distributed in digital form.

The questionnaire was structured in six sections. In section A teachers' personal data were recorded (gender, age, didactic experience, etc.). In section B primary teachers were asked to express how important it was for their students to develop specific STEM practices in the classroom or lab. In section C, participants were asked to estimate how often their students actually develop the same STEM practices in the classroom or lab. In section D and section E primary teachers were asked about their self-efficacy in teaching science and mathematics. Section F included 4 open-ended questions so that teachers could express themselves in detail and comprehensively. The questionnaire was inspired by similar studies (Gatan et al., 2021) and was based on the questionnaire developed by North Carolina State University (Friday Institute for Educational Innovation, 2012).

Content validity is covered by the fact that all questionnaire items refer to primary teachers' views on STEM education and at the same time all aspects of STEM education are included in the considered items (Gay et al., 2012). The content of the questionnaire was double tested by two experts in STEM education, who both agreed on all items (Polit & Beck, 2006).

Moreover, a total of 27 structured in-voice interviews lasting about 7-10 minutes each was used to cross-check or refine teachers views on STEM education. The interviews were given voluntarily by teachers who had previously answered the questionnaire, were recorded with teachers' consent and then transcribed verbatim.

Table 1. Teachers' views on the development of students' scientific thinking

How important do you consider the development of scientific thinking (formulating questions/hypotheses, design of research, experimental control, communication of results, etc.) by your students and why?	Primary teachers' percentage
Because students learn to solve problems of everyday life	38
Because students are engaged in inquiry and foster critical thinking	26
Because students improve their social skills	15
Because it is a new way of learning (experiential, interdisciplinary, etc.)	12
Because it contributes to the acquisition of knowledge	7
Various answers	7
Answers without justification	18

Note: The number of responses exceeded the sample number because many teachers gave more than one explanation.

Ethical Approval

Formal ethical approval was waived for this study since the design and implementation procedures were followed to ensure ethical standards such as the participants' consent, anonymity of the participants, and password protected data storage.

Data Analysis

Regarding the closed-ended questions, they were sorted based on the pre-determined 1-5 Likert scale grades for each question and recorded in tables. Teachers' answers were presented comparatively according to subject or distance between theory and practice.

Open-ended questionnaire responses as well as the structured interviews have been analyzed qualitatively, thus the given answers have been classified according to their content (Mayring, 2015; Monroe, 2002).

Limitations

Convenient and limited sampling do not allow trustworthy generalizations (Hedt & Pagano, 2011) about the intended population.

RESULTS AND DISCUSSION

Teachers' Views on Students' Scientific Thinking

At the beginning primary teachers were asked in the questionnaire how important they consider the development of their students' scientific thinking and why. According to participants' answers, the development of students' scientific thinking is considered either very important (63%) or extremely important (20%). **Table 1** depicts teachers' justification derived by the corresponding open-ended question.

A significant percentage (38%) of the teachers referred to reasons related to the importance of developing scientific thinking for everyday life. Most of them describe it as a "life skill", others think it helps students in managing problems, and others think it works as a "transfer" of school science experience to students' everyday lives. These views were variously emphasized in the interviews as well:

> "It is very important, because students gradually learn to solve problems on their own using various tools, techniques … and then they can also solve broader problems concerning society, such as the environmental ones, recycling …" (PT4).

> "It is very important, because through the steps of the scientific methodology, students can learn to deal with various situations in their daily lives" (PT16).

> "… it is very important, because in modern times we have to think scientifically, use technology, understand environmental problems …" (PT23).

This finding was also identified in the research of Karakaya et al. (2020), when it was reported by students, and in the surveys of Nuangchalerm (2018) and Bal and Bedir (2021), when it was reported by teachers.

A total of 26% of the teachers believe that scientific thinking improves students' motivation and intellectual abilities, as it engages them in inquiry and fosters their critical thinking. Some answers during the interviews enlighten the field:

> "It is very important for students to be able to explain phenomena that happen around them and to think rationally, to interpret correctly, not to attribute animistic characteristics to the phenomena" (PT3).

> "… because they arrive at rational proofs … acquire a flow of thought … with productive reasoning … and draw correct conclusions so as to avoid misinformation" (PT17).

> "It is very important, because they will learn to think out of the box, to be more flexible, not to parrot, to approach the issues in different ways …" (PT8).

> "… development of rationale, things that are proven experimentally, so critical thinking is also developed" (PT17).

The comparative advantage of STEM education was given by a teacher, as follows:

> "At school, students practice solving problems, mainly in science lessons, but they don't learn to think as much out of the box as in STEM" (PT4).

Similar findings have been recorded in the research of Roberts et al. (2018), when students stated that they extended their knowledge through experimentation, while in Nuangchalerm's (2018) research analytical thinking emerged as a highly recognized aspect of STEM education.

A total of 15% of the teachers emphasize that scientific thinking improves students' social skills, such as active participation, cooperation and creativity. These characteristics were also mentioned spontaneously during the interviews:

> "… it is important, because it makes the student reach some conclusions on his own, to act on his own and not have the teacher give him ready-made solutions …" (PT27).

> "It is necessary for the students to ask the questions themselves, not to offer them ready-made knowledge, as has been the case for so many years, to make their own assumptions, to question themselves …" (PT7).

> "… students benefit from cooperation and teamwork …" (PT24).

Great improvement in students' ability to work in groups was recorded in the research of Karakaya et al. (2020) and a large positive difference in the emotional response to the learning process in the form of STEM education was recorded in the research of Roberts et al. (2018). Moreover, our findings confirm those referring to the improvement of students' self-efficacy (Lamb et al., 2015) or self-confidence (Bal & Bedir, 2021) and those referring to teachers' STEM teaching efficacy (Nadelson et al., 2012).

A percentage of 12% of the sample believe that scientific thinking is an attractive way of learning including experientiality, interdisciplinarity and argumentation:

> "… it is very important, because they can approach science and math in a more playful way …" (PT26).

> "… it is very important that students engage in hands-on activities …" (PT25).

> "… the students showed great interest, they highlighted environmental issues, the constructions were the final product …" (PT21).

> "… it is a discovery and reflective process, it interests students a lot … it can combine many things together that create questions for students and thus lead them to knowledge …" (PT18).

Table 2. Teachers' views on fundamental STEM practices

Practices acquired by students:	In my opinion, how important is for students in the classroom or lab to …	How often in the classroom or lab my students can …
Develop problem-solving skills through small investigations in the context of science, mathematics, or technology lessons	75%	8%
Work in small groups	70%	19%
Make predictions that can be tested experimentally	70%	9%
Make careful observations and measurements	69%	7%
Use measuring instruments and data collection tools (calculators, computers, rulers, balances, etc.)	70%	17%
Recognize "patterns" in data	58%	13%
Create logical explanations of the results of an experiment or a small investigation carried out as part of the lesson	70%	13%
Share the results of their work (such as projects) with their classmates through small presentations made in class	70%	18%

Note: The percentages refer to the teachers' responses to the highest grade of the 1–5 Likert scale of the questions (those who answered 5 = very much).

Finally, 7% of the sample point out in the questionnaire that scientific thinking contributes to the acquisition of knowledge, as confirmed by the interviews:

> "It is very important, because it is the basis for understanding the natural world" (PT12).

> "… scientific thinking is foundation of knowledge …" (PT22).

Interviews shed light on some more aspects. Teachers had the opportunity to express their concern regarding the role STEM education can play in diminishing inequalities in school and beyond. Specifically, they mentioned loudly that giving emphasis on the scientific method in class enhances all students' access not only in science and technology, but in everyday life as well. In their own words:

> "Scientific thinking is very important for all students, because it helps all students' participation in class, and not only the favor ones" (PT15).

Some teachers thought that the scientific thinking provides a solid ground in order to help students drive themselves "safely" in everyday life especially in heterogeneous classes in the post-COVID-19 era.

Moreover, the cultivation of scientific thinking through STEM education was justified by teachers in social terms and was considered as a factor in reducing the existing social inequalities. In their own words:

> "Today, thinking scientifically is necessary, because the development of technology is rapid in the labor market, society, economy, science and all students should be ready for this trend" (PT11).

In other words, teachers feel responsible about the extent to which school is able to prepare all students, and not only the privileged ones, for the labor market and life in general:

> "I believe that in recent years with the development of technology and the expansion of knowledge subjects, it is necessary if we redefine the syllabuses and see what knowledge all future citizens must have given that science is developing at a dizzying pace and the information that is bombarding students is huge" (PT10).

Teachers' Views on Fundamental STEM Practices

Table 2 compares teachers' views on eight basic practices acquired by students through STEM education. The comparison consists of the difference between how important teachers consider the acquisition of each practice and how often their students can cultivate it in real classroom or laboratory settings.

Most of the teachers (70-75%) consider it important to acquire the practice of problem solving, working in small groups, making predictions that can be tested experimentally, making observations and measurements,

Table 3. Teachers' competencies in teaching STEM subjects

Teaching the subject	Science	Mathematics
I am constantly improving my teaching practices in the subject	23%	33%
I feel confident that I can teach the subject effectively	20%	36%
When a student has difficulty to understand a subject concept, I feel adequate to help him/her to understand it better	24%	40%
During the teaching the subject I feel quite safe to provoke questions from my students	29%	42%
I know what to do to increase students' interest in the subject	21%	27%

Note: The percentages refer to the teachers' responses to the highest grade of the 1–5 Likert scale of the questions (those who answered 5 = very much).

collecting data, providing logical explanations and presenting the results of an investigation. Recognizing patterns in data seems to be less important (58%).

Regarding teachers' answers on how often their students can work on such STEM practices in the classroom, they are significantly less (7-19%). Such a finding implies that teachers, although they find STEM practices significant for students' education, cannot support their teaching and implementation in class. In other words, a contrast is found between the practices that teachers consider very important for students and the minimal opportunities they create to cultivate them. Therefore, everyday school life is far from both the beliefs of the teachers and the requirements of the curricula, which either implicitly or explicitly suggest the systematic cultivation of these practices through the teaching of many school subjects, such as science.

It is notable that the highest percentage of teachers who believe that students have often the opportunity to develop a practice in the classroom or in the laboratory reaches only 19% and refers to working in small groups. This is followed by the presentation of results (18%) and the use of measuring instruments (17%), while the percentages for making predictions that can be tested experimentally, for problem-solving skills through small investigations and for careful observations and measurements are disappointingly low (**Table 2**).

The findings of the questionnaire were also confirmed by the interviews. The entire sample considers the development of students' scientific thinking important, but the individual basic practices acquired by students through STEM education were not listed as important in such high percentages. Moreover, the pursuit of their acquisition by students in real classroom or laboratory conditions was stated as rather rare, despite the recognition of STEM as an important subject:

> "It is an important approach to education through technology, in an effort to introduce students to issues they will encounter in their lives" (PT10).

> "Its basic philosophy is to use specific research scientific procedures of data collection in order to arrive at a conclusion and a practical application. STEM unify theory with real life" (PT9).

Although teachers in the interviews listed many points of STEM education, suggesting many of the practices in **Table 2**, they admit that they are neglected in the classroom or laboratory. In the following questions, an attempt is made to justify the reasons for this great opposition and the teachers' position on their personal responsibility.

Teachers' Adequacy in Teaching STEM Subjects

Table 3 shows the results of the self-reported competence of the teachers in the teaching of science and mathematics, the fields of STEM that are taught as distinct subjects in the Greek primary education.

It appears that only 20–30% of teachers report that they teach science effectively and only 30-40% report that they teach mathematics effectively in primary school. This is a finding that has been found in the literature also (Avery & Meyer, 2012; Bjerke & Solomon, 2019). However, the present research, in the light of more interdisciplinary approaches that STEM education requires, reveals a lack of confidence, insecurity and in some cases fear about teaching these subjects, which ultimately extends to the overall methodology and application of STEM education:

> "... insecurity and hesitancy around this way of approaching teaching" (PT8).

Table 4. Teachers' views on STEM education advantages

What do you see as the main advantages of STEM education?	Primary teachers' percentage
It is a new and attractive way of learning (experiential, interdisciplinary, with playful activities, etc.)	46
It connects school with everyday life through problem solving	38
It introduces students to scientific methodology through experimentation and technology	32
It cultivates cooperation and teamwork	29
Engage students in inquiry/discovery through creativity	29
It increases students' interest in active participation and cultivates critical thinking	25
Various answers	6
I do not know	5

Note: The number of responses exceeds the sample number because many teachers gave more than one answer.

> "... and the fear of the unknown" (PT16).
>
> "There is a fear of teachers and students that their effort will fail" (PT20).
>
> "The fear of failure due to my own lack of experience" (PT22).

Comparatively, however, it appears that primary teachers are more familiar with teaching mathematics than science. This is probably due to the fact that mathematics is taught in all grades of primary school, while science is a separate subject only in grade 5-grade 6. Moreover, demands for experiential teaching probably increase the anxiety and insecurity of many teachers in science, which is not the case in mathematics. Finally, it is worth mentioning that the subjects of technology and engineering are not taught separately in the Greek primary school and are approached by students only indirectly through applications of science in everyday life.

These findings of the questionnaire seem to concern a part of the teachers, as they stated with great sincerity and honesty during the interviews:

> "I would like a comprehensive training, not online, especially in small grades that are not directly taught science ..." (PT25).
>
> "I need equipment ... lesson plans and guidance ..." (PT24).
>
> "... hardware infrastructure and information for teachers with examples, so that we are not afraid..." (PT22).
>
> "Along with tutorials I would like to have my own PC in the classroom with downloaded software and some IT guidance" (PT21).

However, it seems that teacher insecurity is more related to the lack of equipment or handling new materials than to the teaching of concepts in science and mathematics or the attitude of students towards STEM education.

Teachers' Views on STEM Education Advantages

When the teachers were asked in the questionnaire what are the advantages of STEM education, they answered with similar arguments to the cultivation of scientific thinking, albeit with a different order of priority (**Table 4**).

A significant 46% of teachers consider that STEM education is a new and attractive way of learning characterized by experiential, interdisciplinary and playful activities, as confirmed in the interviews:

> "STEM education promotes interdisciplinarity" (PT1).
>
> "The interdisciplinarity, the open-mind of the perspective, the combinatory way of thinking, the handling of objects, so students become scientists and craftsmen at the same time" (PT17).

A significant 38% of the sample connect STEM education with issues of daily life mainly through problem solving:

> "Students learn to search, investigate, question, find information, use information and connect it to their lives, to their everyday life" (PT1).
>
> "It helps students develop scientific thinking, encourages them to work together, gives a very experiential way of learning, connects school knowledge with real life" (PT9).
>
> "Students realize that what they learn can be applied in life" (PT7).
>
> "... students combine science with their everyday life and are introduced to technology" (PT6).

A percentage of 32% considers that STEM education contributes to new student competencies, such as the use of new technologies, persistence in experimental confirmation and practice in scientific methodology:

> "It helps students to work in a context, organized, with a final goal, searching for knowledge, in groups, to arrive at a solution ..." (PT15).

A percentage of 29% emphasize that STEM education cultivates the ability to cooperate and develops team spirit:

> "The most important thing is that students work in groups!" (PT7).
>
> "The development of partnerships!" (PT21).

29% believe that STEM education broadens students' intellectual perspectives either through inquiry or creativity:

> "The student is active, he/she doesn't just obey to the teacher, he/she cooperates, exchanges ideas, develops his /her critical thinking, learns by playing, better understands what he/she learned so far through books" (PT20).
>
> "STEM education opens horizons, opens the mind, gives students opportunities for more searches" (PT12).

In a long-term perspective, this qualification could be considered as the basis for a professional career in a STEM-related field, as stated by students in various surveys (Karakaya et al., 2020; Stefanidou et al., 2023).

Finally, 25% of teachers believe that STEM education motivates students to participate, increases their interest, cultivates their critical thinking and many other skills:

> "Students investigate on their own, they discover, they find the mistake, they are creative, they divide the work, everyone takes a role, they are happy ..." (PT4).
>
> "... students construct their own knowledge ..." (PT13).
>
> "STEM education makes learning more attractive, the students leave the book, the mind and body are activated, it is a student-centered teaching" (PT11).
>
> "Collaboration and critical thinking are developed. Students use their knowledge and can arrive at a solution or to give an explanation" (PT4).

This finding also confirms those of other studies (Bal & Bedir, 2021; El-Deghaidy et al., 2017; Nuangchalerm, 2018), which refer to students' active engagement and interest increase.

According to these findings, it seems that primary teachers consider STEM education to have many educational advantages. It is noteworthy that the referred strong aspects of STEM education include interdisciplinarity and hands-on activities, features that primary teachers have approached in previous years

Table 5. Teachers' views on STEM education weaknesses

What do you see as the main weaknesses of STEM education?	Primary teachers' percentage
The lack of teacher training and the limited availability of educational materials	58
The lack of infrastructure and equipment in schools and the high purchase costs	42
The lack of sufficient time and the unclear place of STEM education in the curriculum	31
The danger of over-attachment to techno-centrism	3
None	3
I do not know	7

Note: The number of responses exceeds the sample number because many teachers gave more than one answer.

through environmental education and education for sustainability (Mandrikas, 2015). In addition, the teachers emphasized the possibility of student self-acting and construction of knowledge:

> "It's more interesting for the students, they do things by themselves, they experiment, they use simple materials" (PT16).

Finally, some teachers emphasized that STEM education provides equal opportunities:

> "… that all students are engaged…" (PT25).

> "… some students with language difficulties work better because they use their hands …" (PT26).

> "… some students have opportunities they would not otherwise have" (PT10).

STEM education, therefore, can also be seen through the lenses of reducing inequalities in education, as it provides the opportunity to participate and take initiatives for students who are not considered "academically good enough".

Teachers' Views on STEM Education Weaknesses

When teachers were asked in the questionnaire (open-ended question) about the weaknesses of STEM education, their answers formed three trends, a trend related to cognitive difficulties of teachers, a trend related to technical and operational difficulties of schools, and a more general trend referring to a lack of sufficient time (**Table 5**).

The first group includes answers (58%) about the lack of training of teachers, the difficulty of organizing the class and adapting to the students' knowledge and the limited availability of educational materials. The interviews confirmed the specific needs:

> "… lack of information among teachers …" (PT12).

> "A teacher lacks very specific training" (PT25).

> "… teachers need specialization with experiential seminars" (PT4).

> "The teacher is asked to implement something in which he is not sufficiently trained … he/she does not feel able to implement STEM education as an innovation" (PT10).

> "We do not trust ourselves "(PT7).

As expected, this finding is also present in literature "… teachers are interested but not well prepared …" (Shernoff et al., 2017), "… lack of teachers' preparedness …" (El-Deghaidy et al., 2017), and "… an urgent need for … trainings …" (Toma & Greca, 2018).

The second group includes answers (42%) about the lack of infrastructure and equipment in schools and about the high cost of the required equipment. Teachers' interviews confirm what was recorded in the questionnaire:

> "The weaknesses are not of STEM education; they are of our own infrastructure!" (PT22).

Table 6. Teachers' needs for successful implementation of STEM Education

What support would you like to receive so that you can implement the STEM education in your classroom?	Primary teachers' percentage
I need more training on the subject	71
Appropriate infrastructure and equipment are needed in schools	31
More training material is needed	21
I need constant support and guidance	16
I need to attend sample teachings (teaching scenarios, best practices, video lessons, etc.)	13
Need more time for STEM education in timetables, reduction of curriculum material and reshaping of the curriculum	11

Note: The number of responses exceeds the sample number because many teachers gave more than one answer.

> "We need materials and technical infrastructure that we don't have in schools, even simple materials …" (PT17).

> "The biggest problem is the cost of electrical and electronic equipment" (PT21).

> "There is no equipment at the school, we have to ask the students for a lot of materials …" (PT2).

> "Money is needed to buy tablets, materials and technical infrastructure!" (PT5).

Similar findings have been recorded in the study on students' views by Karakaya et al. (2020) and in the studies on teachers' views by Bal and Badir (2021), El-Deghaidy et al. (2017), and Shernoff et al. (2017).

The third group (31%) explicitly includes the lack of sufficient time and the unclear place of STEM education in the curriculum. Some typical answers:

> "We don't have much time as the constructions are time consuming" (PT6).

> "We are running out of time! We are pressed to cover the curricula material … and the rush is at the expense of quality …" (PT9).

> "We are running out of time! It is impossible to deal in depth, to research, to construct, to present in such a short time!" (PT18).

An experienced primary teacher concluded her thought, as follows:

> "I don't think that STEM education has weak points, it's just that its implementation is stuck in time. If we deeply deal with STEM education, the students will learn 10% of the knowledge very well and see its practical application. However, we would leave the rest of the curriculum matter and we would have a problem with the parents …" (PT23).

Explicit references to insufficient time to complete experiments or other experiential activities have been made in the survey about students' views by Karakaya et al. (2020) and in the surveys about teachers' views by Toma and Greca (2018), El-Deghaidy et al. (2017), and Shernoff et al. (2017).

It is noteworthy that only 3% of teachers pointed out the worry of over-attachment to techno-centrism. All the remaining responses essentially referred to the conditions for the successful implementation of STEM education in schools, responses that were confirmed by both the responses in **Table 6** and the interviews:

> "The weak points are not issues related to the structure of STEM education, but difficulties arising from the way STEM education is implemented in the school" (PT9).

> "More time is needed in the school, materials and technical infrastructure and teachers' information" (PT15).

However, a point of teachers' honesty and self-awareness was also found here, as primary teachers recognized their own difficulties and weaknesses:

> "Teachers have learned to teach from their seat in the classroom and it is difficult for them to change ..." (PT2).

Need for Support for Successful Implementation of STEM Education

When the teachers were asked in the questionnaire what kind of support they would like to receive in order to implement STEM education in the classroom, they largely focused on their personal cognitive weaknesses (**Table 6**). A significant 71% requested more training on the subject, 21% requested more training materials, 16% requested ongoing support and guidance, and 13% requested to attend sample tutorials (**Table 6).** These responses were confirmed in the interviews, where the experiential and practical nature of the requested training seminars was highlighted:

> "I would like a training that includes practical applications, what lessons could be connected, what educational goals does it cover in small grades ..." (PT27).

> "Seminars with theoretical and more practical training ..." (PT26).

> "In-class seminars, materials, ready practices, timetables" (PT19).

> "A substantial basic training with sample teachings and workshops with experiential participation" (PT14).

In the questionnaires, primary teachers gave more priority to personal educational needs than in the incomplete infrastructures and non-existent equipment in schools (31%) or the need to allocate more teaching time for STEM education in the timetable (11%). However, in the interviews these requests were predominant:

> "Infrastructure should be self-evident, schools need more money" (PT2).

> "Better technological equipment, internet connection, hand material, simulations to show to students ..." (PT7).

> "Unfortunately, there is a lack of financial possibility for the purchase of materials ... the ministry considers such issues to have been solved ..., even though we are talking about simple materials, cardboard, paints ..." (PT10).

> "Reorganization of the curriculum and the teaching time, so that we have space to apply STEM education" (PT9).

> "More time! Make STEM a distinct subject! In this case, they would also provide us with materials ..." (PT23).

In general, we respect the request for technical and financial support to schools, but it is equally important that teachers know what STEM education is in essence. For example, they need to know how to cover learning objectives in the individual subjects by applying STEM education or how to work interdisciplinary on a STEM problem. This is what they themselves seemed to be asking for during the interviews:

> "... Training seminars, teacher groups for communication, interaction and exchange of ideas ..." (PT13).

> "... seminar courses, practical training with detailed guidance, good mood and financial ability for materials, tablet, internet and more time ..." (PT20).

> "... information, training seminars, instructions, a direction in the class, people to support me, equipment in the physics-chemistry laboratory ..." (PT12).

In some cases, the teachers also asked for a manual, so that they would have more and more precise guidance:

> "Equipment, training and teaching scenarios in a manual with realistic and applicable topics" (PT16).

> "There should be steps that the teacher must follow. A manual–teacher's guide for each thematic unit … accompanied to seminars and provision of materials and software" (PT15).

This finding also confirms that of Toma and Greca (2018), when teachers demanded more guided instructions and textbooks as the main material of STEM instruction (p. 1390).

Some teachers, convinced of the value of STEM education, wondered whether they should take more initiative:

> "Is it worth it to limit the curriculum matter? Should we drop something from some courses to deal with STEM education?" (PT20).

Such thoughts are fueled by the positive reception of STEM education by students:

> "The introduction of STEM education was a pleasant surprise! Despite my hesitations, the students showed great interest, brought their own materials, made presentations and are asking to continue even more" (PT21).

> "The students reacted with great enthusiasm and interest, because they used their hands, eyes, ears, their whole body. They like action and variety…" (PT19).

This positive reception of STEM education by the students in some cases also creates in the teachers

> "… mood to follow something new" (PT11).

This finding confirms that of Nadelson et al. (2012), when great progress was recorded in teachers' pedagogical contentment after participating in STEM activities.

Finally, many teachers emphasized their desire for co-teaching and for the exchange of ideas between colleagues,

> "Ideally, a second teacher would be needed in the classroom …" (PT2).

> "Scientific support from colleagues and cooperation between colleagues is needed …" (PT5).

> "I want help from colleagues …" (PT8).

> "… creating a team at school …" (PT11).

In general, the request for continuing support, mentoring programs and participation in a community of practice has also been expressed in literature (Shernoff et al., 2017; Toma & Greca, 2018).

CONCLUSIONS AND TEACHING IMPLICATIONS

Greek teachers consider STEM education as an innovative and interdisciplinary approach to science combined with mathematics, technology and IT, while also having pedagogical advantages:

> "It's a combination of science and technology. Also, it is an opportunity for students to approach topics that have been a bit difficult so far and an opportunity for students who have difficulty approaching learning" (PT26).

They do not have a negative attitude towards his introduction to primary education, but they consider that it has been done

> "… with hesitation, with anxiety …" (PT20).

> "... entered a little violently ..." (PT15).
>
> "It was a rough and disorganized introduction this year" (PT16).
>
> "This year's introduction was stressful" (PT17).

The conditions proposed for the successful introduction of STEM education at least in primary education are clear: training of teachers, provision of infrastructure and equipment and more time in the timetable are needed. The students are considered to adapt easily to the requirements of STEM education and through such activities cultivate many social skills, such as cooperation, taking initiative, decision making and the exchange of ideas and arguments.

In this research, some rather unexpected findings were welcome, that refer mainly to how teachers perceive STEM education as an educational tool against inequities. Several teachers pointed this out by saying

> "STEM education for me is a modern and necessary approach to practical lessons, which connects the student to society" (PT1).
>
> "... teaches students practically, helps them think better, get up from the desk, socialize, work in groups, don't get bored, show more interest ..." (PT8).
>
> "... students benefit from cooperation, which is a very important competence ..." (PT24).

In other words, teachers highlighted increased opportunities for students' socialization, for improving their social skills, for more and more active participation, especially for those who lag in formal lessons either because of lack of courage or because of learning difficulties or because of social origin. The difference of STEM education is the offering of freedom in the way of thinking and the way of organizing the work up to the result and its presentation. A remarkable and comprehensive explanation of this impact of STEM education was given by one teacher in the interviews

> "STEM education reduces the inequalities between students, it gives opportunities to those who don't have any!" (PT1),

opening the dialogue for STEM education to contribute to the goals of critical education.

Such a perspective paves the way for further research which could deepen on teachers' views concerning the relationship of STEM education with critical education. Furthermore, another research could investigate teachers' practices to emerge students' critical views through STEM activities or to record students' views about fundamental aspects of critical education after participating in a STEM oriented program. In any case, the case of Greece concerning STEM introduction in compulsory education is indicative: an approach presented as modern and innovative by the official educational policy is introduced without the necessary prerequisites in public school and left to the discretionary effort of teachers. However, this is the easy way to blame teachers for ineffective implementation of STEM education. In contrast, this survey highlighted the willingness of teachers to implement STEM education and their cry for help from the relevant educational agencies.

Author contributions: Both authors contributed equally to this work. Both authors approved the final version of the article.

Funding: The authors received no financial support for the research and/or authorship of this article.

Acknowledgments: The authors would like to thank the teachers who volunteered to be interviewed.

Ethics declaration: The authors declared that this study was approved by National and Kapodistrian University of Athens, Athens, Greece. Design and implementation procedures were followed to ensure ethical standards such as the participants' consent, anonymity of the participants, and password protected data storage.

Declaration of interest: The authors declared no competing interest.

Data availability: Data generated or analyzed during this study are available from the authors on request.

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