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Brief Report

Approaches to STEM Education Around the World, What We Can Learn from Them?

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Abstract: The article commences with a historical review of STEM education, followed by a discussion of its implementation across various nations worldwide. The objective of the research is to identify and categorize the diverse approaches to implementing STEM education, with a view to establishing standards that can serve as a model for its introduction in other countries. The primary conclusion of the research is that while STEM education can be incorporated into a nation's educational system, it does not necessitate the entire curriculum being based on it.

Keywords: STEM education; curriculum; STEM approaches

Introduction

The initial link between disparate scientific disciplines, and by extension STEM, can be traced back to Ancient Greece, where Aristotle and Hippocrates devoted themselves to the study of their immediate environment. The conceptualization of mathematics as a scientific discipline can be traced back to the works of Pythagoras, while its integration into engineering and infrastructure construction followed shortly thereafter. The subsequent industrial revolutions that ensued precipitated a profound transformation in the everyday landscape and, by extension, the educational sector (Unesco & Boon, 2019). During the Second World War, the military and scientists collaborated to apply the new technologies of the era, and this collaboration was also necessary to end the war. This example demonstrates the application of STEM, but not in education (Widya, Rifandi, & Rahmi, 2019).

The acronym STEM, an abbreviation for Science, Technology, Engineering and Mathematics, signifies a pedagogical approach that integrates the principles of the aforementioned disciplines, namely physics, chemistry, biology, geology, technology, mathematics and engineering. In this paradigm, students are encouraged to approach each problem through an interdisciplinary lens, a method that fosters the development of multiple skills. The overarching objective of STEM education is to cultivate professionals who possess the capacity to devise innovative solutions by synthesizing knowledge from diverse fields.

The necessity to enhance the teaching of science and mathematics in the United States has been a matter of pressing concern since the early 1980s. This has given rise to a focus on STEM (Science, Technology, Engineering and Mathematics) education, as evidenced by the National Science Foundation's (NSF) numerous references to this subject in its reports (Breiner, Johnson, Harkness, & Koehler, 2012). The impetus for these changes stems from the global economy, which is undergoing significant transformation (Kenned & Odell, 2014), as well as the need to maintain national economic competitiveness (Maass, Geiger, Ariza, & et.al., 2019) . By the close of the decade, a plethora of publications by various associations articulated their objective of fostering scientific literacy among the American populace. During the 1990s, the endeavors to fortify the science discipline garnered support from associations representing elementary, secondary, and higher education teachers. The culmination of these endeavors was the formulation of innovative curricula

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in science, mathematics, engineering, and technology (SMET) (Breiner, Johnson, Harkness, & Koehler, 2012) . The advantages of this type of education were such that it was elevated to the top of the U.S. policy agenda (Blackley & Howell, 2015). In order to ensure the success of the introduction of this new form of education, it was deemed necessary to inform teachers, especially those who teach at undergraduate level (National Science Foundation, 1996).

Concurrently, and extending up to the first years of the 21st century, research across multiple countries has documented a decline in the pursuit of these disciplines by secondary school students, accompanied by a decline in admissions to universities to study, primarily, physics and mathematics. Specifically, within the United Kingdom, between 1990 and 2008, there was a 49% decline in physics enrolment and a 26% decline in chemistry enrolment (Bøe, Henriksen, Lyons, & Schreiner, 2011).

The acronym STEM (Science, Technology, Engineering and Mathematics) began to be used in the early years of the 21st century, as the word SMET was considered to resemble the word smut (smoke).In order to make it clear that the union of sciences is done with the aim of strengthening the educational system and that no reference is made to any other field, the term STEM Education was used. In 2005, Virginia Tech University established the first curriculum with a central theme of STEM education (Integrative STEM Education) (Sanders, 2009). [9]. By the close of the decade, a rapid increase in the initiation of new curricula on the subject of STEM and the corresponding doctoral theses was observed (Moore & Smith, 2014). [10].

From 2007 onwards, the significance of STEM education as a catalyst for success, both in the acquisition of knowledge during school years and in the development of professional skills for future careers, began to be recognized (Breiner, Johnson, Harkness, & Koehler, 2012). The influence of the arts (primarily literature) and social sciences on the scientific field was first documented in the literature by Yakman G. in her 2008 thesis. Notably, she introduced the term STE@M, where the middle @ symbolizes the arts, and was the first to propose an educational framework integrating the sciences and the arts. It is important to note that the term arts does not exclusively refer to the fine arts, but also encompasses a wide range of skills not included in scientific disciplines (Yakman G. , 2008).

In 2009, the University of Minnesota established the University of Minnesota STEM Education Center with the objective of enhancing this particular type of education (Moore & Smith, 2014). In 2010, reference was made to the misunderstanding of many students regarding STEM education, who, despite the numerous applications of engineering and technology in everyday life, when referring to STEM, primarily associate it with mathematics and natural sciences. The article further elucidates the primary objective of STEM education as fostering a profound comprehension of the interplay between natural laws and human accomplishments, while concomitantly enhancing technological literacy.It is imperative to re-evaluate the role of engineering, recognizing its nexus with competencies such as problem-solving and the generation of innovative solutions, which are indispensable in both professional and national contexts (Bybee, 2010). In 2011, John Maeda, representing the Rhode Island School of Design (RISD), articulated a strong advocacy for the transition of STEM to STEAM, a position informed by his own multidisciplinary background as an artist, graphic designer, computer scientist, and educator (Maeda, 2011). The integration of arts into STEM has been posited as a means to enhance the comprehensibility of information and the aesthetic appeal of products (Piro, 2010). In 2011, the Korean Ministry of Education adopted a similar approach by proposing the integration of arts into STEM learning, thereby transitioning to a STEAM-based educational framework (Widya, Rifandi, & Rahmi, 2019).

In 2012, Yakman G. & Lee H. made a compelling case for the inclusion of the arts in a publication concerning STEM education in Korea, arguing for the transformation of STEM into STEAM. This transformation, they asserted, would be informed by the rich philosophical, psychological and sociological traditions found in the arts sector. They contended that the arts had played a significant role in the development of human civilization, and that this should be recognized as a fundamental aspect of any comprehensive STEAM education. This paper proposes a novel definition for each constituent of the acronym, representing a significant advancement in the field (Yakman & Lee, 2012).

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The integration of fine arts has been demonstrated to foster students' creativity, a skill that is increasingly recognized as a vital component of 21st-century learning (Aguilera & Ortiz- Revilla, 2021). Furthermore, the amalgamation of convergent thinking, which is imperative in the context of scientific problem-solving, with divergent thinking, which characterizes humanities and artistic disciplines, has been shown to be a catalyst for innovation (Yakman & Lee, 2012). The integration of non-STEM disciplines fosters the development of imagination and creativity, which have frequently been the catalyst for scientific innovation (Shukshina, et al., 2021). In 2013, the International Council of Association For Science Education (I.C.A.S.E.) in Kuching emphasized the necessity to link STEM education with contemporary issues, such as environmental protection and sustainability (EDUCATION, 2013). This declaration observed a trend of science being more outward-looking towards society, offering a novel perspective on this type of education. It also reflected the need to connect what students can learn from scientific disciplines with issues that concern both ethical and humanitarian factors. While the connection with the seventeen UN sustainability goals is clear, an extension of this connection is the cultivation of moral values and feelings such as social justice and equality (racial and gender).

In 2015, the report on the US education strategy stated that mathematics, natural sciences, technology and engineering should be regarded as interconnected concepts, given their relevance in everyday life (Council, 2020).

In 2019, the UNESCO International Bureau for Education (IBE) emphasised the necessity of integrating STEM disciplines with non-STEM ones, acknowledging the blurring of boundaries between the two disciplines in the context of the ongoing Industrial Revolution 4.0. The report also underscored the importance of aligning educational goals with the 2030 Sustainable Development Goals. It is noteworthy that the term STEM has evolved to encompass a broad spectrum of specialties within the professional sector, extending beyond the traditional scientific domain (Unesco & Boon, 2019).

The objective of this article is to examine the global interest in STEM education and its implementation in various countries. The article undertakes a systematic analysis of the implementation strategies employed in different nations. The present article aims to identify the model applications of STEM education, with a view to implementation in a greater number of countries.

Methodology

The present article was composed through utilisation of the methodology of literature review.

STEM Education in Different Nations

A substantial number of studies, predominantly in developed countries, have been conducted to evaluate the adequacy of STEM education received by students. The comparison of the findings from these studies is challenging due to the varying contexts of each nation, the divergent policies enacted by policymakers regarding STEM education, and the differing models of equal participation between men and women (Bøe, Henriksen, Lyons, & Schreiner, 2011). The implementation of STEM education varies significantly across countries, necessitating a country-specific report on the implementation method. In the USA, the STEM education curricula are founded on three pillars: the application of scientific and engineering practices, and the integration of science with engineering (Roehrig, El-Deghaidy, García-Holgado, & Kansan, 2022).

Research in the USA has highlighted two key issues. Firstly, the low quality of this type of education has been identified, and secondly, the inequality of access to it by the various social groups of students has been demonstrated.The quality of education that students receive is influenced by the poverty rates in the neighbourhoods in which they live, as this affects children's cognitive and verbal abilities as well as their academic performance. Concurrently, racial segregation is evident, as black Americans predominantly reside in economically disadvantaged neighbourhoods (Xie, Fang, & Shauman, 2015). Moreover, women are underrepresented in STEM professions (McDonald, 2016),

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signifying a concomitant diminution in educational opportunities in these disciplines.A noteworthy finding of the research is the observation that students in developing countries exhibit a greater inclination to pursue STEM professions compared to their counterparts in developed countries. While most of them make the decision on whether to pursue STEM education during their secondary education (McDonald, 2016). Consequently, the provision of this type of education in secondary schools is considered vital for the realisation of its objectives.In the U.S., there are four different types of STEM schools:

- STEM selective schools, including
- STEM-focused schools,
- STEM-focused Career and Technical Education, and
- STEM education in non-STEM-focused schools (Tang Wee Teo, STEM Education Landscape: The Case of Singapore, 2019).

In Saudi Arabia, the implementation of STEM methods has exposed deficiencies, primarily concerning the teachers' preparedness to utilise these methods and to teach in this manner. This has led to the identification of numerous misconceptions among teachers regarding this pedagogical approach (Widya, Rifandi, & Rahmi, 2019). Concurrently, the necessity for training those who apply the principles of STEM education in their classrooms has become increasingly apparent. In Malaysia, an endeavour to integrate STEM education into the teaching of subjects has been undertaken since 2017. The challenges encountered in this context are analogous to those observed in other countries, with inadequate teacher training, insufficient technological resources, and curriculum design being the primary issues (Widya, Rifandi, & Rahmi, 2019).

In 2011, the Korean Ministry of Education made the decision to introduce arts education, and consequently STEAM education, in response to the observed lack of interest among students in pursuing studies in STEAM fields after completion of their secondary education, despite the implementation of STEM methods and the high success rates of students in mathematics in the PISA competition. The challenges experienced by teachers included an excessive workload, difficulties in allocating time for lesson preparation, and challenges in utilizing new equipment (Widya, Rifandi, & Rahmi, 2019).

In the majority of countries, there is a disproportionate underrepresentation of women in engineering, physics, mathematics and technology. This issue hinders the development of STEM as women can contribute to the advancement of these disciplines with their unique perspectives (Bøe, Henriksen, Lyons, & Schreiner, 2011).

Another significant finding of the research is the perception among young people that science is generally important for human development, but not for them as individuals (Bøe, Henriksen, Lyons, & Schreiner, 2011). This incongruity suggests a lack of awareness among students regarding the prospects for professional advancement and the acquisition of transferable skills that stem from engagement with science-related domains. The high salaries that STEM graduates receive during their professional careers serve as a motivating factor for other young individuals to pursue this field of study. Conversely, the complexity, high cost and considerable difficulty of these studies act as deterrents. In a study conducted by Wahono et al. In 2020, a study of 54 different studies was conducted on a total of 4768 students of all levels (mainly secondary education) and students in Asia in order to draw a conclusion about how much STEM courses were able to help students acquire higher-order reasoning as they help in decision-making, problem solving, implementing innovations and creativity.The criterion for the success of STEM follows the following reasoning path:

The following criteria were used to assess the success of STEM:

-Acquisition of higher-order reasoning

-Academic achievements of students

-Motivation

The learning outcomes of the studies in which the meta-analysis was conducted were also divided into the aforementioned categories (Wahono, Lin, & Chang, 2020).

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In this study, STEM education was defined as a combination of the areas mentioned in the acronym, with the objective of providing solutions to real-world problems. As in the USA, so in Asia, the promotion of STEM education was a result of the ever-decreasing interest of young people to engage in STEM professions. The overarching objectives of the study can be delineated into three distinct axes:

- The influence of STEM education, originating from the USA, on the learning outcomes of Asian students
- The identification of a specific factor that strengthens STEM education
- The aggregation of information on the implementation and development of this educational model in Asian countries (Wahono, Lin, & Chang, 2020).

The results of the study demonstrated that the impact of STEM on learning outcomes and academic knowledge ranges at medium levels. The impact of STEM on learning outcomes appears to vary across different regions, with higher rates of improvement observed in Southeast Asian countries compared to others. Additionally, STEM education has been found to have a significant impact on enhancing students' motivation and higher-order reasoning skills, surpassing the impact on other categories. A secondary finding of the research was that greater improvement due to the implementation of STEM was observed in regions where lower performance in the PISA competition is observed than in those that are ranked in the top positions in their scores. Consequently, it can be concluded that STEM education may be more beneficial for students who do not have the ability to develop higher-order reasoning. The temporal aspect of STEM education has also been identified as a critical factor in its effectiveness; it is posited that the longer students engage with STEM education, the more significant the results in relation to the criteria established in this study. It is noteworthy that the efficacy of STEM education is influenced by the teaching method and educational approach employed by the instructor. In conclusion, the results of STEM education in Asia are deemed to be favorable (Wahono, Lin, & Chang, 2020).

In developed areas of China, such as Shanghai and Zhejiang Province, there have already begun to be the first signs of convergence between STEM education and industrial development. The establishment of the STEM Education Innovation Centre has as its primary purpose the promotion of STEM education, which is intertwined with innovation. In China, the acquisition of scientific and technological knowledge from school age is considered a key plow through which the future industrial and economic development of the country can be achieved. To this end, the STEM Education 2029 action plan has been implemented in all provinces to advance STEM education. However, the initiative is currently limited to a few schools in the most developed areas, with the primary challenges being a lack of teacher awareness regarding the implementation of these methods and inadequate equipment in many schools. The overarching objective of the Chinese government is to elevate the nation to a position of pre-eminence in the global arena of innovation, a goal which is being pursued through the establishment of a symbiotic relationship between industry and education (Quan, 2020).

In 2017, the Chinese Ministry of Education incorporated mandatory interdisciplinary methodologies into the curriculum for natural sciences in primary schools, thereby encouraging teachers to utilize STEM methods. In numerous cities across the country, endeavors have been made to promote STEM education, either through the dissemination of information to teachers or the establishment of STEM groups within educational institutions. For instance, in March 2018, Zhejiang Province organized 15 training programs, sending teachers of all levels to be trained in STEM education in countries that have already developed this type of education (Quan, 2020).

In Hong Kong, the first mention of STEM education was made in 2015, and since then it has been promoted in both primary and secondary education, as it was considered a great opportunity to promote the cultivation of skills important to students (Wong & Shih, 2022). The development of STEM education in these regions has been driven by several key factors, including the introduction of extracurricular activities, the promotion of participation in competitions and exhibitions, and collaboration with organizations specializing in STEM skills. It is noteworthy that the definition of

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STEM education is becoming increasingly broad, with the use of Information and Communication Technology (ICT) being sufficient for its characterization. The interdisciplinary approach to a given topic and the successful combination of STEM disciplines are ultimately more closely related to the abilities and enthusiasm of the teaching staff to transmit their knowledge to their students than to the existence of a well-designed framework within the curriculum (Leung, 2020). A disadvantage of the system is that it does not provide students with the opportunity to conduct research, as instructions for problem-solving are provided along with sample answers. Consequently, the work of each group is similar, as the same model is repeatedly reproduced. Additionally, students are not given the opportunity to develop their own model-building skills. To address these issues, the proposal is to implement STEM education (Wong & Shih, 2022).

Germany's performance in the 2000 PISA competition was not particularly commendable, and consequently direct interventions were made so that teachers focused more on achieving specific learning objectives and less on curricula. This enabled teachers to enjoy greater autonomy in their approach to each learning objective. In this context, STEM education and the multidimensional goals it represents were implemented, while at the same time ensuring the high quality of this type of teaching. The preparation of assignments is an important tool for STEM education, however, in German physics and mathematics textbooks there are no corresponding incentives for their implementation (Schiepe-Tiska, Heinle, DÃ¼mig, Reinhold, & Reiss, 2021).

In Indonesia, STEM education has been implemented since 2014, with a pilot school programme already in place in which STEM education is applied. In the near future, cooperation between school units and universities is expected to enable students to acquire 21st century skills. To this end, researchers collated scientific articles pertaining to STEM education as implemented in Indonesia, with the articles in question having been published from 2015 to 2020.The percentage of articles related to STEM education demonstrated a continuous increase, with the maximum percentage appearing in 2019. The slight decrease in 2020 can be attributed to the impact of the COVD-19 pandemic. This continuous trend of increasing articles is indicative of the growing interest among scholars in STEM education and, by extension, the increasing number of schools implementing it. It is noteworthy that the primary application of this pedagogical approach, as evidenced by the extant literature, appears to be with junior high school students. Furthermore, there is heterogeneity in the provinces of Indonesia that opt to implement them (Farwati, et al., 2021).

In Singapore, the education system is predicated on STEM education and serves as a global exemplar for the acquisition of 21st-century skills, as it engenders a learner-centric pedagogy that emphasizes the acquisition of learning skills over the transmission of content (Gonzalez-Perez & Ramirez-Montoya, 2022). In the country, the approach to this type of education is holistic, with many different institutions contributing to it, with the Ministry of Education leading the way. In 2005, the National University of Singapore established a Mathematics and Science High School (NUS High), which was staffed by specialized STEM education teachers who held master's and doctoral degrees. In this school, students conducted independent research under the supervision of their teachers. The objective of this initiative was to provide a nurturing environment for gifted students, thereby laying the foundation for a STEM-oriented educational paradigm. Subsequent to this, in 2010, the School of Science and Technology (SST) was inaugurated as a four-year institution. This school, in collaboration with the Polytechnics, aspires to offer educational experiences that are applicable to real-life scenarios. The promotion of this educational model was further reinforced in 2013, encompassing both primary and secondary education. To this end, schools engaged in the STEM programme were granted the autonomy to devise their own curriculum, with the support of private entities and industries or university institutions. The initiative is further bolstered by competitions in STEM-related fields, catering to students from schools not pursuing this educational path (Tang Wee Teo, STEM Education Landscape: The Case of Singapore, 2019). The success of the Singaporean education system is indisputably linked to the integration of STEM education, as evidenced by the commendable scores attained by students in international assessments such as the PISA competition. It is important to acknowledge that, in addition to the schools with a primary focus on STEM, a

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significant number of programmes are funded for the rest, and concurrent efforts are being made to train teachers in the methods and practices of STEM education (Tang Wee Teo & Tang Wee Teo, Singapore Math and Science Education Innovation, 2021).

The 47th Report of the UK Parliament for the period 2017-2018 makes reference to the STEM skills deemed necessary for the development and strengthening of the country's economy, with a clear emphasis on supporting students in acquiring the relevant skills (Delivering STEM skills for the economy., 2017-2019). Concurrently, a new position of National STEM Director was established, who was tasked with the creation of a new action plan encompassing 11 distinct programs. The programmes primarily emphasized the teaching of natural sciences and mathematics, with less emphasis on engineering and technology (Darwish & Darwish, 2019).

In Japan, the absence of a clearly defined framework for STEM education results in its utilization in mathematics and natural sciences, albeit not consistently throughout the curriculum. Despite the establishment of fundamental learning objectives encompassing all STEM-related competencies in 2017 by the relevant Ministry, the integration of these competencies into the curriculum remains limited. In Japan, there is a prevalence of misinterpretations of methods by teachers, and while learning engineering as a separate subject is completely absent from primary and secondary education (Yata, Ohtani, & Isobe, 2020).

In Egypt, the reform in favor of STEM education began in 2011 with the establishment of the first STEM school, while by 2022 the number of schools had risen to 19. The overarching objective of this initiative was to enhance the quality of education and equip students with the requisite skills for successful entry into the workforce. The initial phase of the programme was implemented in collaboration with the relevant Egyptian Ministry and educational companies from the USA, with the primary aim being the transfer of knowledge related to STEM education. In these Egyptian schools, students are organized into groups to work on tasks, with collaboration with University Institutions and Research Centers being strongly encouraged. It is noteworthy that all schools are under the auspices of the Ministry, ensuring uniformity in curriculum and assessment methods (El Nagdi & Roehrig, 2022). The schools are equipped with technological resources, with a focus on problem-solving in real-life scenarios, such as finding drinking water and reducing traffic congestion (Roehrig, El-Deghaidy, García-Holgado, & Kansan, 2022).

In Spain, the curriculum is based on the European Framework of Reference for Key Competences for Lifelong Learning. Despite the clear reference by the European Union to the introduction of STEM in education as a guarantee for the acquisition of the expected skills, the Spanish government does not include Engineering among them. Thus, at a central level, the contribution of natural sciences, mathematics and technology is recognized. Efforts to integrate engineering are made by individual initiatives, such as the establishment of a network of STEM schools by the Community of Madrid (Roehrig, El-Deghaidy, García-Holgado, & Kansan, 2022).

In Turkey, the first recognition of the value of STEM education came from the Turkish Industry and Business Association (TUSIAD), which in 2014 published a report on the market demand for the respective professions. Following the publication of this report, STEM festivals were organized throughout the country by university institutions. In 2016, the Ministry of Education initiated the promotion of these methods in schools, with an emphasis on updating and enriching the curricula to incorporate STEM education. The creation of STEM education centers and the training of teachers were also key initiatives (Roehrig, El-Deghaidy, García-Holgado, & Kansan, 2022). In 2018, the secondary education curriculum was revised to include the acquisition of skills in mathematics that are essential for the 21st century. Corresponding changes were also made in the natural science subjects where reference is made to the acquisition of skills in engineering, directly referring to STEM education (Sen, Ay, & Kiray, 2018).

In Russia, the first mention of the need to introduce STEM education in the country was made in 2014 by the President. From that moment on, the support measures taken were directly oriented towards engineering through robotics. Through these methods, the development of science and technology will also be achieved. Immediate emphasis was placed on the procurement of essential

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equipment for educational institutions, and the establishment of STEM parks by universities and technological institutes has been observed, with the objective of providing support to primary and secondary education students. To facilitate the training of teachers, postgraduate STEM education programs have been developed by university institutions, which teachers can attend. The expected competencies of students are aligned with their ability to work collaboratively, engage in experimentation, design, assembly and programming of robots (Shukshina, et al., 2021).

In Canada, the majority of endeavors to enhance STEM education are associated with the financial support of specific programs by universities and organizations across various provinces (DeCoito, 2016).

In Brazil, given the high poverty rate, the primary objective of education is to enhance the education system. The significance of STEM education is acknowledged, however, due to the prevailing circumstances, its focus is predominantly on mathematics. In the context of mathematics education, there is a focus on preparing work that addresses local community concerns, such as consumer education, which encompasses concepts related to percentage and the monetary system. Conversely, the teaching of natural sciences, including subjects such as physics, chemistry, biology and geology, is not conducted as discrete subjects in compulsory education, which hinders the implementation of STEM methodologies. Nevertheless, the potential contribution of STEM education to the country's economic development has been recognized, and efforts are being made to strengthen it (Milton & Daniel Clark, 2017). For instance, a change in the curriculum was made in 2020, which provides for the integration of STEAM education into the daily lives of students (Pugliese & De Macedo Santos, 2022). It is also worth noting that a public announcement was made calling for the collection of STEAM educational materials in order to take a holistic approach to the effort (Pugliese & De Macedo Santos, 2022).

STEM in Greece

Despite the continuous reforms of the nation's education system and the efforts to make progress, there is an absence of a comprehensive national strategy regarding STEM education. The low scores achieved by Greek students in the PISA competition demonstrate a lack of critical thinking, problem-solving ability and, in general, basic 21st-century skills. Concurrently, the prevailing context, characterised by stringent curricula, the inadequacy of the student evaluation system, and the diminution of teaching profession prestige, engenders further impediments to the implementation of STEM educational systems (Σ.Ε.Β., 2021).

The majority of endeavors to incorporate STEM education are concentrated in private secondary education, yet even within this domain, the initiatives are predominantly isolated. These endeavors are regarded as significant, as they signify initial efforts to incorporate STEM education into the Greek educational landscape and stimulate interest among students in the respective scientific disciplines. It is noteworthy that the majority of these initiatives are undertaken by private entities, such as the Educational Robotics Organization (Cosmote) and Generation Next (Vodafone). Significant acknowledgement is warranted for the endeavors of educators, both collectively (e.g., Union of Greek Physicists) and individually, in their efforts to integrate STEM education into the Greek school system (Σ.Ε.Β., 2021). A notable initiative in this regard can be identified as the introduction of the Skills Labs course (Σ.Ε.Β., 2021), marking a pioneering endeavor on the part of those responsible for implementing this change. The course has been introduced in all grades of primary and secondary school with the publication of the Government Gazette B-3567/4.8.2021, and its objectives are defined in the same publication as follows:

- 21st century skills (communication, critical thinking, creativity, collaboration, digital collaboration, etc.)

life skills, technology, engineering and science skills (creation and sharing of digital works, technological literacy, robotics, etc.) and mental skills (e.g. computational thinking, thinking routines, problem solving).During an academic year, students must study at least one topic from each thematic

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unit, with each unit also aiming to develop a category of skills mentioned above (Φ.Ε.Κ. Β/3567, 04/08/2021).

The Ministry of Education and Religious Affairs, cognizant of the prevailing changes at the scientific, social and technological levels, is undertaking a comprehensive review of the curricula (Ι.Ε.Π., 2023). The new curricula are scheduled for implementation in educational institutions across the country from the 2023-2024 academic year. The study of the curricula is considered appropriate on the grounds that they constitute the first coordinated effort of STEM education in our country, while it is the first time that a clear reference is made to it. According to what is stated on the website of the Institute of Educational Policy (IEP) regarding the new curricula, clear references are made to the objectives of the new curricula which are consistent with those of STEM education. More specifically, it is stated:

- The cultivation of the competencies requisite for the citizens of the 21st century.
- The alignment of school education with scientific advancements.
- The utilisation of the knowledge acquired by students at a subsequent time.
- Innovation, efficiency and creativity are some of the key characteristics of the new school.
- The establishment of coherent connections between different subjects, as well as between the same subject from class to class.
- The integration of elements of everyday and modern life.
- The acquisition of metacognitive skills (learning how to learn) (Ι.Ε.Π., 2023).

The ensuing discourse will pertain to the curricula of natural sciences, technology, engineering and mathematics, with a view to elucidating the points of direct or indirect reference to STEM education.

Discussion

A comparative analysis of data pertaining to the implementation of STEM education in various countries reveals a universal recognition among educational policymakers of the necessity for students to acquire 21st-century skills. This necessity is further compounded by the imperative for students to develop the capacity to effectively address challenges encountered in their daily lives. Consequently, there is a consensus that STEM education has the potential to significantly contribute to this endeavour.

Between 2014 and 2017, a significant number of countries appear to have initiated a shift towards STEM education, including Malaysia, China, Hong Kong, Indonesia, the United Kingdom, Japan, Turkey and Russia. Earlier examples include Germany in 2000, Korea in 2011 and Singapore in 2005. As the 21st century progresses, the majority of nations are endeavoring to transition towards STEM education, recognizing the necessity for citizens to possess the skills required to contribute to their respective countries' economic development. It is noteworthy that the aforementioned transition periods coincide with the development of STEM education in these countries. The 2013 I.C.A.S.E. event represented a significant milestone in this regard, as it underscored the connection between STEM education and not only the development of skills but also sustainability. Consequently, the subsequent adoption of STEM education by numerous countries after 2014 cannot be viewed as a mere coincidence. A notable point pertains to the fact that, for many countries, the outcomes of the PISA Competition served as a catalyst for the introduction of STEM education. For instance, Germany introduced STEM education following its underperformance in the 2000 Competition, while Korea has successfully combined STEM education with high performance in the Competition. Another factor that appears to be related to the implementation of STEM education is the country's economic situation, which is not surprising given the logistical demands of fully equipped laboratories and classrooms. For example, Brazil recognizes the importance of STEM education but is unable to implement it due to a lack of appropriate logistical support. Conversely, Russia's strategic shift towards STEM education, with a pronounced emphasis on robotics and engineering, has been accompanied by the allocation of essential equipment to educational institutions, a measure that aligns with the nation's economic capabilities.

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A further distinction between the approaches of these nations pertains to the integration of STEM education into their respective curricula. Illustrative of this, Turkey, China and Singapore have modified their curricula to ensure that all students have access to STEM education. In contrast, Germany has not undergone a change in its curricula, but has instead made them more flexible, thus enabling the integration of STEM education into schools.

In Greece, the most recent revision to the curricula was undertaken in 2023, with the objective of implementing them from the 2023–2024 academic year. This signifies a later initiation of this process in comparison to the aforementioned countries. A pervasive theme across all curricula is the emphasis on acquiring 21st-century skills, metacognitive abilities, problem-solving skills, and higher-order thinking skills. It is noteworthy that STEM education has the potential to contribute to the attainment of these objectives. However, the references to STEM education are predominantly found in the Technology course, which is offered in all secondary school grades but is allocated only one teaching hour per week. Additionally, the Physics course in Primary, Middle and High School includes explicit references to STEM education, with a focus on fostering students' recognition of the interconnected nature of mathematics with other disciplines. An alternative approach to STEM education, emulated in nations such as Egypt, Singapore and the USA, involves the establishment of dedicated STEM schools. The merits of this approach lie in the availability of specialized teaching staff, who can impart knowledge in the requisite methods. However, this approach is not without its drawbacks, particularly in terms of its capacity to ensure equitable access to STEM education for all students.

In Hong Kong, Spain, Canada and Indonesia, the integration of STEM education is predominantly associated with extracurricular activities, with its implementation being reinforced by external factors such as universities and organizations. A proportion of these extracurricular activities involves participation in student competitions, which aligns with the approach adopted in our country. Student competitions organized by private entities are overseen by the Ministry of Education and Religious Affairs. It is noteworthy that the majority of these competitions pertain to robotics rather than encompassing STEM education in its entirety.

Conclusions

STEM education has unquestionably garnered the global interest of educational systems. Due to its inherent interdisciplinary nature, it is evident that it can be applied in numerous forms. Implementation of STEM education is expected to yield positive results in terms of enhancing students' 21st century skills and their subsequent engagement with STEM disciplines.

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