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Traits of Stem Teachers for 21st Century Stem Education

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Abstract

STEM education is a growing global trend, but what are the essential characteristics that should be cultivated in the curricula of the higher education institutions that teachers attend, as well as through the training programmers they follow throughout their careers? This literature review aims to identify the characteristics that a STEM educator should possess in order to achieve the goals of such education. Beyond basic pedagogical knowledge, educators themselves need to acquire 21st century skills. As mentors, they are responsible for setting a positive example for their students. A STEM classroom is characterized by democratic principles and the desire to find innovative solutions. The teacher is the intermediary between the goals of the educational system and their achievement. It is therefore essential to study the aspects of their training that can contribute to this direction.

Keywords: STEM Education, Secondary Education, Teacher Skills, 21st Century Skills.

Introduction

Education can be defined as the process by which individuals develop the capacity for learning Within the school environment, this process is facilitated by the dissemination of information from the educator to the learner [1, 2]. The objectives of education are subject to constant modification, adapting to the novel contexts established by each era, thereby necessitating a corresponding adaptation in the competencies required of educators to facilitate the achievement of these objectives through teaching [3].

In the 21st century, educational systems are confronted with changes that are impossible to ignore [4-6]. The primary driving force behind these changes is the global economy, which is in a state of constant flux [7]. The Industrial Revolution 4.0 0 has imposed the use of new technologies (UNESCO, 2020) such as deep learning and artificial intelligence in education [8-13].

The changing social and natural environment is another key factor. The phenomenon of globalization, migration, population ageing, climate change and overpopulation have given greater importance to the acquisition of 21st-century skills and have changed data in education [14, 15].

The necessity to interconnect education with concepts such as sustainability is also of paramount importance. Consequently, students and future active citizens must be equipped with the skills to overcome any challenge in the ever-evolving conditions and to manage situations in their daily lives as adults [16, 17].

Humanistic education aims to instill ethical principles in every decision that the individual makes and the habit of thinking before acting [18]. The education that the individual receives is responsible for protecting the well-being of society through the knowledge and skills that they will acquire in order to respond to an uncertain future. More specifically, the skills that the individual is expected to acquire during their schooling are the skills of the 21st century. Concomitantly, it is considered necessary for students to embrace values such as sustainability. STEM education is a proposal that can combine both the acquisition of skills and values [19].

The professional competencies that teachers must acquire are inextricably linked to the overarching educational goal, which is the skill that students are expected to acquire at the conclusion of the educational process. In order to achieve this goal, teachers are required, in addition to in-depth knowledge of their subject, to employ innovative pedagogical methods (Mandal, 2018) .

It is acknowledged that the development of these skills in students

is contingent on the teacher's prior mastery of them. In light of this, the article proposes fundamental strategies to facilitate the acquisition of each skill by students.21st century skills are characterized by their complexity and the inability of machines to replicate them [20].

As 21st century skills remain undefined, this article will analyse the following skills:

- Problem solving. [21-23].
- Creativity [24].
- Critical thinking.
- Collaboration.
- lifelong learning.
- Adaptability [25]

which are explicitly mentioned in the literature as part of 21st century skills. 21st century skills are now being considered in the creation of new curricula, as the latter are thus aligned with the demands of the labor market [26]. The acquisition of these skills is in full alignment with the goals of STEM education [27, 28]. Through these skills and STEM education, students in their adult lives are qualified professionals and active citizens [29-32].

As previously mentioned, STEM education focuses on the acquisition of 21st-century skills, which is why it is considered appropriate to provide its definition and its main goals. The individual fields overlap; the set of skills that the individual acquires at the end of their education are those that will make them competitive in the 21st-century labor market. The lesson scenarios employed in this context necessitate an interdisciplinary approach, integrating knowledge from a minimum of two scientific disciplines [33]. Conversely, alternative definitions of STEM education stipulate the construction of a mechanical analogue during the educational process as a prerequisite [34, 35].

The role of the teacher is multifaceted; they are charged with the responsibility of managing situations, observing students, and organising the educational process [36]. The teacher is the one who is responsible for teaching, that is, for transmitting knowledge to students. It is the teacher's responsibility to assess the conditions in their classroom and select the most suitable educational methods to achieve the desired objectives. In addition, 21st-century teachers must be proficient in the skills they will impart to their students [37-39]. These skills are transmitted through communication and interaction with students [40].

In the contemporary educational environment, characterised by technological advancements, environmental shifts, and globalisation, educators must possess the requisite resources and competencies in relevant educational methodologies to effectively address these challenges. Initially, educators must identify the desired skills, which in the context of this study are problem-solving, creativity, critical thinking, collaboration, lifelong learning, adaptability. In essence, the acquisition of 21st-century skills should be prioritised as a central objective, with the implementation of STEM education serving as a catalyst for achieving this goal. The role of the teacher has historically been multifaceted.

On the one hand, the teacher serves as a role model for students, a mentor, and thus sets an example for them through his own behaviour and actions [41, 42]. The primary function of the teacher is to impart their knowledge to students, thereby enhancing their performance. The first component is realised through extensive subject knowledge and meticulously prepared lessons, while the second is achieved through effective classroom management [43]. In the context of educational objectives, the focus has shifted from the mere acquisition of knowledge to the cultivation of 21st-century skills. This paradigm shift is emphasised by the United Nations Educational, Scientific and Cultural Organization (UNESCO), as articulated in the seminal work of Wang and Jia [44]. The pedagogical paradigm shift entails a broadening of goals, extending beyond the mere transmission of knowledge, to encompass the cultivation of critical thinking and the facilitation of communication across all levels. The role of the teacher, as the architect of learning, becomes pivotal in shaping the skills and competencies that students will acquire. It is vital to acknowledge the significance of the training that teachers receive during their studies, with governments aiming to enhance the curricula in teacher training colleges to align with the educational requirements of the 21st century.

In the context of rapidly evolving environmental conditions, influenced by technological advancements, the climate crisis, refugee movements, globalisation, and other factors, the role of the teacher assumes paramount importance. The present study aims to address this lacuna in the international literature by synthesising the fundamental competencies and skills that teachers must possess to implement STEM education, as well as strategies to cultivate 21st-century skills in their students. Research undertaken in Istanbul, Saudi Arabia, Greece and China, indicates that teachers themselves do not perceive themselves as competent in implementing STEM education [45-48]. Concurrently, while there is considerable global interest in STEM education, there is a paucity of research in the context of the practices employed and the educational objectives.

This underscores the significance of the present study, as it aims to orient teachers regarding the requisite skills and to facilitate their comprehension of the accessibility of STEM education to all educators. Consequently, the article can serve as a foundational framework for the training of STEM teachers. Initially, the demands that this educational paradigm imposes on the teacher and the design of the lesson are addressed. Finally, the article discusses how teachers can contribute to the development of students' fundamental 21st-century skills.

The research document is expected to provide answers to the following key questions:

1. What 21st-century skills are essential for a STEM teacher to master, and what strategies can be employed to ensure that these skills are effectively transferred to students?
2. How can STEM education contribute to the achievement of this objective?

General Teachers' knowledge.

A teacher's knowledge can be divided into four components, each of which plays an important role in achieving the final goal. These four components are

- assessment
- pedagogy
- curriculum

about students [49].

In the context of educational system reforms, and the evolution that accompanies the passage of time, teachers are the first to be called upon to adapt. In order to achieve this ambitious goal, teachers must adapt both their knowledge and the pedagogical methods they will apply. The globalisation of society, coupled with the digitalisation of many everyday life processes, means that all teachers in the world must acquire the same skills.

As previously mentioned, the transmission of knowledge constitutes one facet of a teacher's role, with the other facet pertaining to their social skills. To enhance their effectiveness, teachers must nurture their interpersonal relationships with individuals with whom they will engage in their professional milieu [50].

Methods and Materials

The present study was conducted using the bibliographic review method. In accordance with this approach, articles were searched for using search engines such as Google Scholar and MDPI. The search was conducted by entering various keywords into the search engine, including 'STEM teacher', 'skills development' and 'teacher characteristics'.

Stem Education Requirements

The implementation of STEM education in the classroom necessitates a multifaceted set of competencies from the teaching faculty. Teachers' positive sentiments towards this pedagogical approach can facilitate its integration. This objective can be more readily accomplished if educators recognise the potential of STEM education to enhance students' academic performance.

In addition, a teacher who utilises STEM education should possess not only in-depth knowledge of their own field of specialisation but also a breadth of understanding across other disciplines. During the lesson, they must demonstrate the interconnection of the subject matter with the specific lesson, as well as with other disciplines and with issues of everyday life. This approach fosters intrinsic motivations that can lead to advancements in research, design and invention across various fields, marking a departure from conventional teaching methods that rely on the transmission and reproduction of knowledge [51].

It is noteworthy to mention an alternative approach to STEM education that emphasises the utilisation of group teaching to address specific issues. In this approach, the teacher of each STEM specialty delivers the module corresponding to their own cognitive background [52]. This approach obviates the need for teachers to have in-depth knowledge of all fields. However, it does require a high degree of cooperation and coordination, and therefore detailed organisation. This approach renders STEM education more effective. Addressing challenges in the application of engineering, a field that hinders STEM education implementation, necessitates collaboration among teachers. Each teacher contributes their area of expertise, with professionals overseeing engineering, circumventing the need for in-depth knowledge in all fields [53, 54].

The crux of STEM education lies in the resolution of everyday problems. Initially, a authentic problem must be designed and subsequently utilised, following the establishment of learning objectives [55]. The educator must also cultivate an educational environment conducive to students working collaboratively to solve ambiguous problems while deepening their knowledge on the specific issue. Effective teaching entails more than mere transmission of information; therefore, teachers must possess communication and management skills. The utilisation of teamwork methods and a holistic approach can facilitate the achievement of desired objectives. In such an environment, teachers foster positive attitudes in students, which are also influenced by the interaction between class members. The integration of STEM education in the curriculum has been shown to foster positive attitudes in children, potentially paving the way for future STEM careers [56].

The teacher's role is not to provide all the answers, but to guide students towards solutions, nurturing their research skills as they progress. The creation of an environment that fosters encouragement and support for all students, rejecting stereotypes and embracing diversity, is of paramount importance. In this context, students with special needs have access to resources and strategies that can benefit them. While the group as a whole, the students become active and not passive listeners. At the same time, they reach the goal on their own, thus strengthening their motivation regarding their cognitive subject and their persistence in order to achieve the desired result. TABLE 1 provides a synopsis of the data derived from the reviewed bibliography and the document under consideration, which are collectively regarded as data sources.

Table 1 The Following Table Provides a Comprehensive List of the Fundamental Components of Stem Education, as Established in the Extant Literature and Incorporated within the Scope of This Study.

A/A	
1	The primary objective is to cultivate 21st-century skills.
2	A key approach to skill development is problem-solving in everyday life contexts.
3	Teaching requires an interdisciplinary approach.
4	In the context of teaching and learning, there is a growing recognition of the value of interdisciplinary collaboration among educators specialising in the STEM fields.
5	The utilisation of collaborative methodologies has become increasingly prevalent in educational settings.
6	Students are encouraged to engage in active learning processes that involve the collection of information, its analysis and evaluation, and the application of new technologies. They are also expected to engage in experimental activities and the construction of mechanical analogues.
7	The overarching objective of this approach is to foster the acquisition of 21st-century skills that are increasingly recognised as essential for success in a rapidly changing global environment.

Problem Solving

The ability to solve a real-life problem is at the core of the objectives of STEM education, as it connects the knowledge acquired in the classroom with everyday life. The solution that emerges from this educational process is both interdisciplinary, as it considers the data and principles of all the individual fields, and innovative [57, 58].

The onus, therefore, falls on the teacher to meticulously craft a problem that can be solved in an innovative and creative manner, thereby stimulating interest among students. The teacher plays a pivotal role in nurturing the students' inclination to devise innovative solutions. Historically, the decision regarding the educational method employed has resided with the teacher. In the context of STEM education, collaborative methods empower students to engage in cooperative endeavours with their peers and with the instructor, thereby fostering the development of soft skills such as collaboration and communication. The teacher plays a pivotal role throughout the educational process, offering encouragement and facilitating the articulation of students' opinions and ideas. Empirical research consistently demonstrates that the teacher exerts a substantial influence on students' problem-solving abilities.

Creativity

Creativity is considered to be one of the fundamental skills of the 21st century. It is asserted that students can acquire this skill, provided they are in the correct educational environment. It is important to note that creativity is defined as the ability to provide innovative solutions to problem-solving problems.

As outlined in Table 2, there are various methods to enhance students' creativity. In the context of a STEM class aimed at problem-solving, the initial step is to acquaint students with the concept of creativity and the characteristics of a successful solution. It is imperative that the instructor has meticulously delineated the problem to be resolved, ensuring that students are provided with the opportunity to explore it through the lens of diverse STEM disciplines. Simultaneously, it is crucial to emphasize to the students that the endeavor to solve the problem based on scientific criteria, rather than the solution itself, is of paramount importance.

The selection of the method of problem-solving must be conducive to the development of 21st-century skills, particularly communication and cooperation skills. The plenary session of the class should provide an opportunity for students to raise questions regarding the problem, to combine knowledge from different STEM disciplines, and to formulate solutions. The teacher's role is to provide guidance and encouragement, fostering an environment that values student imagination and creativity. The teacher's approach is not to criticize student ideas, but rather to facilitate activities that emerge from student observations or inquiries. These inquiries can serve as catalysts for the development of additional STEM scenarios, encouraging students to think critically and problem-solve.

On an emotional level, the teacher instils in his students the confidence that they will be able to find an innovative solution to the problem they have been given, through research and the interdisciplinary approach required in a STEM scenario. The teacher's ally in cultivating creativity is the use of new technologies, such as virtual reality. The contact of students with new technologies and their ability to use them is another basic goal of STEM education.

Table 2 The Following Table Provides a Synopsis of the Methods by Which Teachers can Foster their Students' Creativity, as Outlined in the Extant Literature.

Reference	Ways to Enhance Creativity
(Ellerton & Kelly, 2021).	It is imperative to first define creativity and the vocabulary associated with it, in order to facilitate its acquisition.
(Ellerton & Kelly, 2021).	It is imperative that the instructor possesses a creative mindset.
(Saidovna, 2022).	The creation of an environment conducive to the development of students' ideas within the classroom setting is paramount [59].
(Saidovna, 2022)	The creation of an environment that is conducive to the desired outcome is imperative.
(Lasky & Yoon, 2020)	The exploration of concepts across diverse scientific disciplines is a multifaceted endeavor [60]
	The pedagogues prioritise the educational process over the attainment of a predetermined outcome.
(Anderson, και συν., 2022)	The teacher employs innovative educational methodologies [61]
	During the educational process, the formulation of questions is supported.
(Anderson, και συν., 2022)	Each inquiry posed by students represents an opportunity for new research, and is addressed by the students themselves, as opposed to being answered directly by the teacher.
(Saidovna, 2022)	It is acknowledged that students have the capacity to initiate the development of activities.
(Saidovna, 2022)	It is imperative to note that the teacher does not undertake any form of evaluation of the students' imagination.
(Saidovna, 2022)	The teacher evinces a high level of confidence in the students' ability to achieve the final objective.

(Norris, Taylor, & Lummis, 2023)	The utilisation of moral rewards by educators has been demonstrated to serve as a motivational tool for students [62].
(Gong, Lee, Soomro, Nanjappan, & Georgiev, 2022)	The utilisation of contemporary technologies, including virtual reality, has been identified as a contributing factor to the enhancement of creativity [63].

Critical Thinking

Critical thinking is another skill that teachers must impart to their students, as it can be cultivated in them through the implementation of suitable methodologies [64].

TABLE 3 enumerates the methods by which teachers can foster critical thinking in their students, as derived from the reviewed bibliography. These data are then adapted to align with the parameters and objectives of a STEM class.

It is evident that educators must possess the requisite training to facilitate this process. The development of critical thinking is predicated on prior knowledge of its definition and the theoretical framework underpinning its cultivation. The meticulous preparation of lessons is equally crucial. In the context of STEM education, the emphasis on real-life problems fosters the growth of critical thinking.

The selection of problems for the classroom should be meticulously designed to incorporate learning objectives that are conducive to the development of critical thinking. These problems must be formulated with meticulous care to ensure that students are able to respond to them, while also necessitating a breadth of knowledge from multiple disciplines to reinforce the value of interdisciplinarity.

The selection of teaching methods is a responsibility that rests with the teacher. Within the context of a STEM classroom, the utilisation of collaborative methods is instrumental in fostering the development of 21st-century skills, such as critical thinking. Subsequent to the formulation of a problem and the selection of an appropriate method, the teacher is tasked with presenting it to their students, accompanied by the stipulated rules that must be adhered to in order for their solution to be deemed acceptable. In the context of critical thinking, the teacher must provide guidelines on the validation of sources and the selection criteria for information derived from these sources. In a STEM classroom, the acceptance of a solution may be contingent upon the utilisation of knowledge from multiple fields of the acronym, as well as the demonstration of an experiment or the construction of a mechanical analogue.

In the context of students' engagement with STEM fields, teachers can incorporate scientific methods into the educational process, such as critiquing articles, participating in discussions, conducting research papers or case studies. The completion of these tasks necessitates information collection, sorting and synthesis, thereby encompassing the fundamental stages of developing critical thinking.

The development of critical thinking in the classroom setting encompasses the facilitation of dialogue and argumentation, the integration of new technologies and concept maps, the formulation of guiding questions, and the engagement of students with diverse information sources, which they are then required to evaluate. The culmination of this process is the evaluation of students' efforts against the criteria and rules established by the teacher from the outset.

Table 3 This Text Provides an Overview of the Bibliographic Data on the Subject of How Teachers can Develop their Students' Critical Thinking Skills.

Reference	
(Alsaleh, 2020).	It is incumbent upon the teacher to possess a sufficient level of familiarity with the definition and theory surrounding critical thinking, and to ensure that these concepts are imparted to their students.
(Ellerton & Kelly, 2021), (Wang & Jia, 2023), (Petre, 2020).	It is imperative to cultivate the ability to think critically.
(Ellerton & Kelly, 2021).	It is imperative that teachers possess not only subject-specific expertise but also the ability to tailor their pedagogy to suit the needs of their students.
(Alsaleh, 2020).	In addition, it is imperative that the instructor be versed in educational methodologies, with the capacity to select an approach that aligns with the learning objectives established.
(Ellerton & Kelly, 2021).	The articulation of cognitive processes through collaborative methodologies.
(Abrami, και συν., 2008)	In order to prepare his lesson in meticulous detail, it is imperative that critical thinking is prioritised [65].
(Abrami, και συν., 2008)	The cultivation of critical thinking skills should be an intrinsic component of any educational programme.
(Fandiño Parra, Muñoz Barriga, López Díaz, & y Galindo Cuesta, 2021).	The planning of classroom activities must be original and focus on learning objectives [66].

(Alsaleh, 2020).	It is imperative to consider the interests of the students in the class.
(van der Zanden, Denessen, Cillessen, & Meijer, 2020).	Engaging with everyday life issues has been demonstrated to enhance students' critical thinking skills [67].
(Alsaleh, 2020).	It is evident that strategies such as the critique of articles, active engagement in discussions, research papers and case studies are to be employed.
(Ellerton & Kelly, 2021).	Prior to the initiation of any designated process, the educator is obliged to provide a comprehensive explanation of the regulations and methodologies that are to be adhered to by the students.
(Ζαβλανός, 2003), (Orhan & Çeviker Ay, 2023) (Petre, 2020).	The emphasis is placed on the analytical interpretation of data and its synthesis [68, 69].
(Meirbekov, Maslova, & Gallyamova, 2022), (Wang & Jia, 2023).	The process of guiding students in the discernment of pertinent information from irrelevant information is of paramount importance.
(Orhan & Çeviker Ay, 2023)	It is imperative to demonstrate to students the methodology employed to evaluate the information they have collected.
(Orhan & Çeviker Ay, 2023)	The following observations were made during teaching sessions: students posed questions.
(Alsaleh, 2020).	The following activities are to be undertaken: the identification of similarities and differences, the recording of data, the classification of data and findings, and the identification of alternative solutions.
(Duncan, Cavera, & Chinn, 2022).	Interference with a multitude of elements of varying quality [70].
(van der Zanden, Denessen, Cillessen, & Meijer, 2020).	The utilisation of dialogue within the classroom environment.
(Ζαβλανός, 2003).	The utilisation of argumentation is imperative.
(van der Zanden, Denessen, Cillessen, & Meijer, 2020).	The implementation of critical thinking is observed in a variety of contexts.
(Ellerton & Kelly, 2021),	It is imperative to engage in a variety of tasks to ensure comprehensive training.
(Meirbekov, Maslova, & Gallyamova, 2022).	The selection of appropriate digital tools is of paramount importance.
(Fandiño Parra, Muñoz Barriga, López Díaz, & y Galindo Cuesta, 2021).	The utilisation of concept maps is a crucial component of this approach.
(Ζαβλανός, 2003).	The development of mutual trust between teacher and students, as well as between team members, is of paramount importance.
(Ellerton & Kelly, 2021)	The following section will provide a detailed analysis of the feedback received on the achievement of learning objectives.
(Ellerton & Kelly, 2021).	The evaluation of students' cognitive processes.

Collaboration

The ability to collaborate is a key requirement for an individual to meet the demands of the 21st century [71].

It is also a basic skill that a teacher must have in order to cope with their duties and to teach it to their students. In a STEM classroom, collaboration is particularly important for three main reasons. First, most of the educational methods used require the formation of groups, so students must collaborate with each other. Secondly, the implementation of a STEM scenario may be facilitated through the collaboration of teachers from diverse disciplines. Finally, the educational process often necessitates interaction and collaboration between teachers and students.

TABLE 4 presents a range of strategies through which teachers can foster the development of collaboration skills in their students. In the context of a STEM classroom, the pedagogical approach should prioritise student collaboration, with groups working towards a solution to a problem in their everyday lives. It is imperative that all members of the group contribute to the shared goal, ensuring the attainment of the learning objectives. The teacher should meticulously design the problem that is subsequently assigned to the students.

Prior to the initiation of the process, the teacher should elucidate to the students, through the utilisation of real-life examples, the significance of cooperation, with particular reference to the contributions of STEM professionals who have collaborated

to address a particular problem. During the students' work, the teacher should facilitate mutual assistance. In a STEM class, the assistance that one student can provide to another may encompass data collection, data processing, experimentation, or the construction of a mechanical analogue. Each stage in this process demands a distinct set of skills, necessitating the involvement of diverse students in the learning process. Another facet of STEM education that fosters collaboration is the recognition that students may arrive at multiple solutions to the same problem. This diversity of solutions is a natural outcome of the scientific method, and educators should foster an environment that values and supports pluralism.

Table 4 This Text Provides an Overview of the Bibliographic Data on the Development of the Skill of Collaboration in Students by Teachers.

Reference	
(Vangrieken, Dochy, Raes, & Kyndt, 2015)	It is imperative that the teacher themselves embody the qualities of a competent collaborator [72].
(Vangrieken, Dochy, Raes, & Kyndt, 2015)	It is imperative that educational staff collaborate to ensure that all teachers implement student-centred and collaborative pedagogical methods.
(Afzal, 2020).	It is imperative to educate students on the significance of collaboration in the context of their future adult and professional lives.
(Afzal, 2020).	The student should be at the centre of the educational process.
(Afzal, 2020).	It is imperative that lesson plans are meticulously designed to facilitate collaborative learning among students.
(Afzal, 2020).	The objective is to devise a series of activities that have the potential to pique the interest of students.
(Liebech-Lie & Sjølie, 2020).	The formation of teams is predicated on the assumption that members will cooperate to reach the final result.
(Faif Pasani & Amelia, 2024)	Collaboration between students is characterised by the exchange of opinions, skills, and joint effort.
(Faif Pasani & Amelia, 2024)	Students are encouraged to engage in collaborative activities following the completion of individual tasks, culminating in a collective synthesis at the project's conclusion.
(Afzal, 2020).	The students are provided with the opportunity to assist one another.
(Lasky & Yoon, 2020).	The concept of a plurality of ideas is endorsed.
(OECD, 2019)	The capacity to adjust to the prevailing conditions at any given moment is paramount [73].
(Faif Pasani & Amelia, 2024)	The utilisation of technologies that facilitate collaboration, including platforms and discussion forums, is imperative in contemporary professional contexts.

Lifelong Learning

The acquisition of the skill of lifelong learning is also considered important for the 21st century. Through this, the teacher will be able to achieve personal and social development, which in turn will have a positive impact on his students [74]. As with all the previous skills, the teacher should first be a lifelong learner but also have embraced values such as equality and solidarity in order to make his students lifelong learners.

As outlined in Table 5, the manner in which educators can foster students' lifelong learning capabilities is elucidated. In a STEM classroom, akin to any educational setting, educators are tasked with the responsibility of selecting an efficacious pedagogical approach to achieve the objective of lifelong learning. This entails the design of problem-solving tasks that transcend a narrow disciplinary focus, encompassing knowledge from diverse fields, and are grounded in both quotidian life and the contemporary labour market.

The teacher's role is not merely to transmit knowledge but to facilitate the acquisition of skills and competencies that will enable students to learn independently and apply their knowledge to real-world contexts. The environment of a STEM classroom fosters the development of the skill of lifelong learning by nurturing curiosity, experimentation and problem-solving skills from the outset. It is evident that a STEM educational environment provides students with the opportunity to develop the skill of lifelong learning. Another salient point of congruence between the skill of lifelong learning and STEM education is the maintenance of skills acquired throughout one's life. In the context of STEM education, the skills, knowledge and interests acquired during school years are intended to be sustained throughout an individual's adult life, thereby enabling them to engage professionally in fields that are projected to experience significant demand in the labour market in the ensuing years.

Table 5 This Text Provides an Overview of the Bibliographic Data on the Subject of How Teachers can Cultivate their Students' Capacity for Lifelong Learning.

Reference	
(Bryce & Withers, 2003)	It is imperative that educators embody a commitment to lifelong learning themselves.
(García-Toledano, Gracia-Zomeño, Farinho, & Picado, 2023)	It is imperative that educators embody values such as equality and solidarity to effectively instill them in their students.
(Tsolaki & Stathopoulou , 2023)	The utilisation of suitable educational methodologies is imperative [75].
(UNESCO, 2020).	It is imperative that the curriculum provides opportunities for the implementation of novel educational methodologies.
(Bryce & Withers, 2003).	The activities that will be selected should facilitate a connection between the educational establishment and the labour market, whilst concomitantly focusing on the enhancement of students' self-esteem.
(UNESCO, 2020).	The teacher's role is not merely to transmit knowledge, but rather to facilitate students' achievement of cognitive goals.
(UNESCO, 2020).	The process is predicated on the maintenance of skills acquired throughout life.
(Tsolaki & Stathopoulou , 2023).	The utilisation of contemporary technologies.
(Bryce & Withers, 2003).	The practice of categorising students according to their performance in classes is to be avoided.
(Bryce & Withers, 2003).	The creation of an environment conducive to the cultivation of curiosity, experimentation, problem solving and the identification of creative solutions is of paramount importance.
(UNESCO, 2020).	Ultimately, the onus falls upon the student to develop the capacity for autonomous learning.

Adaptability

The subsequent pivotal skill pertains to adaptability, which the educator must have mastered in order to inculcate in their students. The adaptability of the educator themselves will facilitate their ability to cope with any unanticipated circumstances that may arise in the classroom.

In Table 6, the actions that a teacher must undertake in order to cultivate the adaptability of their students have been documented. Within the context of a STEM classroom, it is first essential for the teacher to adapt to technological advancements, leveraging technological tools during instruction. As with other competencies, the selection of an appropriate educational method by the teacher is pivotal in cultivating the desired skill in students. The daily life problems posed to students by teachers should be meticulously designed, encompassing achievable goals that gradually increase in complexity. The complexity of real-life problems necessitates a multifaceted approach to problem-solving, encompassing logical thinking, concept association, information synthesis, and argumentation. Collaborative methods are favored in STEM classrooms to cultivate adaptability, with individualized student goals contributing to this end. Within a group, not all its members are required to perform the same tasks or contribute in the same way, so each member can achieve individual goals.

During the problem-solving process in a STEM classroom, there is an increased possibility that the existing knowledge of the students will not be sufficient to solve the problem. The experimental process or construction of a mechanical analogue invariably leads to the encounter of hitherto unexplored conditions, wherein the applicability of extant knowledge to the specific problem may be called into question. Consequently, students are required to relinquish their pre-existing knowledge, revise it, and acquire new knowledge, thereby enhancing their adaptability through metacognitive skills and the educational process of learning, unlearning, and relearning.

The active involvement of students throughout the educational process, whether it be the collection and processing of data, the execution of experiments, or the construction of mechanical analogues, is instrumental in acquiring the requisite skills. It is also imperative for educators to maintain consistency in their instructions and the allotted time for completing the task.

Another facet of the STEM classroom that can enhance students' adaptability is the potential for collaboration between teachers of different specialties to implement an educational scenario.

Table 6 This Text Provides an Overview of the Bibliographic Data on the Development of Adaptability Skills in Students by Teachers.

Reference	
(Akbarovna, 2024) (Larsen, Jensen-Clayton, Curtis, Loughland, & Nguyen, 2023) (Athan & Thacha, 2022)	Once a teacher has attained proficiency, they possess the capacity to adapt to changes, whether these stem from technological advancements or modifications to curricula [76, 77].
(Larsen, Jensen-Clayton, Curtis, Loughland, & Nguyen, 2023)	The period of the pandemic provided an example of rapid and necessary adaptation of teaching methods.

(Akbarovna, 2024)	It is imperative that teachers are able to adapt their teaching strategies in accordance with the characteristics of the class they are addressing.
(Athan & Thacha, 2022),	It is imperative that the objectives established by the instructor for each pupil are distinct, thus enabling them to be accomplished.
(Mawarni, Suwono, & Fachrunnisa, 2021)	Throughout the educational process, the following competencies are cultivated: logical thinking, the correlation between concepts, the ability to synthesise information, the ability to explain and draw conclusions.
(Adu, Omodan, Tsotetsi, & Damoah, 2024, σ. 22)	The purpose of this study is to examine the importance of collaboration between teachers in order to carry out an educational scenario [78].
(Apordo, 2024) (Athan & Thacha, 2022),	The process of goal setting involves the establishment of objectives that are progressively more challenging [79].
(Apordo, 2024)	The process of adapting the behaviour, thoughts and emotions of the teacher is undertaken with the objective of providing support to their students.
(Apordo, 2024; Adu, Omodan, Tsotetsi, & Damoah, 2024, σ. 75)	It is imperative to emphasise the significance of active student participation in the educational process.
(Adu, Omodan, Tsotetsi, & Damoah, 2024, p. 125)	The implementation of educational processes, including learning, unlearning and relearning, is of paramount importance.
(Apordo, 2024)	It is imperative to comprehend the activities that students are required to undertake, the timeframe in which they must be completed, and the amount of time that is available to them.
(Adu, Omodan, Tsotetsi, & Damoah, 2024, σ. 111)	It is imperative that stability is maintained in the rules and structure of the work assigned to students. Any alterations to these elements must be explicitly communicated within the classroom setting. A sense of security is a crucial factor in ensuring optimal student performance.
(Adu, Omodan, Tsotetsi, & Damoah, 2024, p. 18)	The pedagogy of cooperative learning has been demonstrated to respond to individual learning needs and to foster a sense of belonging and appreciation.
(Mawarni, Suwono, & Fachrunnisa, 2021)	The enhancement of students' metacognitive skills is pivotal in empowering them to modify their initial coping strategies for tasks.

Discussion

Teachers are at the heart of the education system. Therefore, improving the skills acquired during their formal education and through lifelong learning ultimately benefits students by improving their academic performance. Throughout their studies and careers, teachers refine their knowledge and skills, broaden their professional horizons and cultivate critical thinking. It is widely accepted that early implementation of this type of education can have positive outcomes. It is therefore becoming increasingly important for teachers at all levels to acquire knowledge in this area.

This research aims to clarify the training goals for STEM educators so that they can be incorporated into teacher education programmes and other professional development initiatives. When teachers in STEM classrooms experience positive emotions, such as joy and happiness, students are more likely to achieve their cognitive goals. These positive emotions not only lead to desired cognitive outcomes, but also create a sense of satisfaction and positive attitudes towards teaching as a profession. Such emotions can be fostered through well-structured curricula in teacher education programmes and professional development courses.

In addition, strong collaboration between school leaders and teachers can create an encouraging environment for the implementation of STEM education. As mentioned above, STEM classrooms are guided by democratic principles and values such as sustainability, reinforced by scientific knowledge and the evolving nature of technology.

Equally important is the development of students' socio-emotional skills, which are linked to better academic performance from early childhood through to secondary education [80]. Teachers can contribute by supporting and communicating effectively with students.

The environment in which every teacher is called upon to teach is demanding and constantly changing, so good initial training and continuous feedback of knowledge is one way of achieving the objectives of modern education systems. A primary component is the teacher's desire to teach their subject and inspire their students. A STEM classroom, in order to lead its students to success - the acquisition of knowledge and skills - must first teach its students values such as respect for others, diversity and the environment.

Conclusions

Going back to the two main questions asked at the beginning of the survey, the answers are as follows:

1. STEM education is a new trend that requires highly qualified teachers. More specifically, the STEM teacher who has first mastered 21st century skills and is familiar with modern pedagogical methods can lead to the achievement of learning objectives and the acquisition by students of the skills necessary for our times. In general, a successful STEM classroom is governed by the basic principles of democracy, as there is a climate of respect, trust, free thinking and expression, cooperation and fair play in this classroom.
2. In the course of their studies or further training, teachers should acquire knowledge of the theoretical framework of 21st century skills. In particular, they should become familiar with the definitions of each skill and the pedagogical methods that can support them. A key feature of all these methods is that they place the learner at the centre of the educational process. The teacher is in the classroom with the primary purpose of ensuring that the rules are followed and that all students are treated equally.

Lessons must be prepared in great detail, making use of new technologies and setting as learning objectives the acquisition not only of knowledge but also of skills. The design must also include authentic everyday problems. Pupils should benefit from the use of new pedagogical methods and exercises. In addition, students should be given an appropriate number of tasks that require knowledge from different areas in order to complete them. These tasks may take the form of research projects, case studies or case histories. The existence of motivation, but also the creation of a positive atmosphere and emotions, the cultivation of curiosity, can also be supportive factors. In the classroom, students are able to ask their questions freely without being subjected to any kind of commentary. Pupils also remain active listeners throughout the lesson, with the teacher supporting them every step of the way.

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