CHETANA
INTERNATIONAL JOURNAL OF EDUCATION (CIJE)
Peer Reviewed/Refereed Journal
(ISSN: 2455-8729 (E) / 2231-3613 (P))
Impact Factor
SJIF 2023 - 7.286

Prof. A.P. Sharma
Founder Editor, CIJE
(25.12.1932 - 09.01.2019)

Advancing STEM Education through STEAM and STREAM Integration Challenges and Opportunities

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First draft received: 12.07.2023, Reviewed: 18.07.2023, Accepted: 26.07.2023, Final proof received: 30.07.2023

Abstract

This article explores the evolution of STEM education, focusing on ways to motivate and engage students in science, technology, engineering, and mathematics. It examines the rise of virtual and remote labs, and the historical development of STEM education as a response to the shortcomings of traditional education systems. The article then delves into the concept of STEAM, where art is integrated into STEM, and further expands the notion of STREAM, which includes Reading as an additional component.

The importance of STEM education is discussed, highlighting its role in developing critical thinking, communication, collaboration, and creativity, referred to as the Four Cs. The National Education Policy (NEP) 2020 in India's context is also considered, emphasizing the significance of STEM education for the country's technological and innovative progress. The article suggests practical methods to implement STEM education, particularly in early childhood, through hands-on and experiential learning. Despite its growing popularity, STEM education faces challenges in terms of resource availability and resistance from some educators.

To address these challenges, the article proposes the inclusion of arts and humanities, fostering empathy, creativity, and interdisciplinary skills, ultimately enhancing students' preparation for a rapidly changing world. By integrating arts and literacy with STEM studies, learners are equipped to face the complexities of the future and contribute positively to society..

Keywords: *STEM, STEAM, STREAM, CREATIVITY, CRITICAL, THINKING, COLLABORATION* etc.

Introduction

Student education in various fields (such as science, technology, engineering, and mathematics) is constantly looking for ways and techniques on how to motivate students to learn, how to increase their engagement and how to increase the efficiency of knowledge acquisition. Information and communication technologies are developing at a very rapid speed and offer many new opportunities that could be used for such purposes.

During the last decade, significant evolution was observed in the area of virtual and remote labs and their deployment in learning and training processes.

What is STEM

STEM education is a widely recognized acronym that encompasses science, technology, engineering, and mathematics, forming the backbone of modern education. The interdisciplinary approach of STEM education seeks to combine theoretical knowledge acquired in the classroom with practical real-world experiences, preparing students to be critical thinkers, problem solvers, and innovators. The objective of STEM education is to provide a holistic understanding of these four subjects, moving away from traditional siloed teaching and towards an integrated and cohesive

approach. The focus is on building a strong foundation of scientific knowledge, critical thinking, and analytical skills, empowering students to apply their learning in a variety of contexts, both inside and outside the classroom. While STEM education is not a new concept, recent attention and emphasis have been placed on finding more engaging and meaningful ways to connect with students, making it a key area of focus for educators worldwide.

History of STEM Education

The emergence of STEM education was a response to the shortcomings of the traditional education system, which lacked focus on key areas such as science and math. The roots of STEM can be traced back to the Morrill Act of 1862, which paved the way for the establishment of land-grant universities to promote agricultural science. The launch of Sputnik by the Soviet Union in 1957 and subsequent Space Race led President Eisenhower to create NASA in 1958 and increased national attention on science education. The rise of personal computers, cell phones, and the internet in more recent times led to an exponential demand for skilled workers in computer science. However, by the end of the 20th century, American students were lagging behind their peers in other industrialized countries in the STEM fields. To address this challenge, the National Science Foundation (NSF) introduced the acronym SMET in 2001 to promote science, math, engineering, and technology standards in K-12 schools. It was later renamed STEM to better reflect the integrated and cohesive approach to education. In the two decades since then, various governmental initiatives such as No Child Left Behind, Educate to Innovate, and the Inspire Act have called for increased funding and emphasis on STEM education. Today, STEM has become an essential component of school curricula. Its focus on real-world applications and interdisciplinary learning prepares students for the challenges of the 21st century, promoting critical thinking, problem-solving, and innovation. The impact of STEM education extends beyond the classroom and is a driving force behind technological progress, economic growth, and global competitiveness.

STEM Education and National Education Policy (NEP) 2020

The NEP 2020 recognizes that STEM education is crucial for India's development, particularly in the areas of technology and innovation. By integrating STEM education into the updated curricula at all levels, the policy aims to strengthen the pool of scientists, engineers, and mathematicians in the country. This will help India become a global leader in technology and innovation, and contribute to its economic growth and development. In addition to emphasizing the core essentials of STEM education, the NEP also focuses on experiential learning, critical thinking, and hands-on training. This approach is designed to foster creativity, problem-solving skills, and a multidisciplinary approach to learning. By introducing subjects such as Artificial Intelligence, Design Thinking, and data science at an early age, the policy seeks to prepare students for the future job market and the changing needs of society. The NEP also recognizes the importance of teacher training and professional development in ensuring the success of STEM education. To this end, the policy proposes a range of measures to improve the quality of teacher training programs and to provide teachers with the necessary skills and resources to teach STEM effectively. This includes providing access to digital resources and training programs, and encouraging collaborations between schools and higher education institutions. Overall, the NEP 2020 represents a significant step forward for STEM education in India. By prioritizing experiential learning, critical thinking, and hands-on training, the policy aims to prepare students for the challenges and opportunities of the 21st century. With its focus on innovation, technology, and multidisciplinary learning, the NEP has the potential to transform education in India and contribute to the country's development in the years to come.

Why STEM Education is Important?

The four Cs

STEM education has become increasingly important in the 21st century due to its emphasis on 21st-century skills such as critical thinking, communication, collaboration, and creativity. The Four Cs are considered essential skills for success in a global economy, and STEM education is a natural extension of these skills. In a study reported by The Washington Post, Bloomberg/Business week and others, employers have expressed concern that many students are unprepared for the workforce, lacking the skills that make them successful employees. Therefore, employers look for excellent soft-skills (4Cs) and STEM aptitude.

Critical Thinking:

Critical thinking is an essential part of STEM education. It involves analyzing an issue or situation objectively based on factual information without any influence from personal feelings, opinions, or biases. Critical thinking comprises several skill subsets, including observation, analysis, inference, and problem-solving, which are integral parts of STEM education. A good example of critical thinking usage is during the Extreme Earth unit, where students learn about layers of the earth, earthquakes, volcanoes, and tsunamis. During the visit on landslides, groups are given a sloping landscape tray on which they must create retaining walls from clay (problem-solving). The goal is to prevent as much erosion as possible to the hillside. Once finished, the tray is backfilled with sand, and a saturating “rain” is simulated. Students must observe the results, analyze any weaknesses in their engineering, and make inferences on ways to improve their design.

Communication:

Communication is crucial in any work industry, and STEM education emphasizes its importance. Candidates must be able to communicate in many different mediums such as presentations, email, and formal written documents. During STEM projects, not only do students have to communicate well with one another, but they must be able to describe or explain

their thought process. The ability to do so in a clear, articulate manner is of paramount importance. During the Air and Water unit, for example, groups are challenged to create a filtration device from plastic bottles and a variety of materials such as cotton balls, coffee filters, sand, charcoal, etc. Once completed, they test their device by passing dirty water through it. However, the challenge doesn't end there! The project is staged as an episode of Shark Tank, and teams are given a budget, and each of the possible filtration materials has a cost assigned to it. This way, the students not only have to think in terms of what will produce the clearest water but also yield the highest profit margin. Once the testing is complete, each team must use excellent communication skills as they "pitch" their device to the teacher.

Collaboration:

Collaboration is an essential part of STEM education. While students sometimes work on their own individual projects, they usually work together collaboratively to complete the project at hand. As they strive to find a harmonious balance between the more assertive personalities and more timid ones, they learn to appreciate and value differing approaches and solutions. STEM education teaches students to work well with others, which is a life skill that will pay dividends long after graduation. The class is divided into five tables, each of which ideally accommodates four students, although some tables have only three students due to varying class sizes. These are mixed by gender so that most tables group together two boys and two girls.

Creativity:

STEM education encourages creativity, in the workplace. When students learn to think critically, communicate effectively, collaborate with others, and be creative in their approach to problem-solving, they are building a skill set that will serve them well in any career they choose to pursue. STEM education provides students with an opportunity to develop these skills in a real-world context, using hands-on activities and projects to reinforce their learning.

Another reason STEM is important is its relevance to our modern world. We live in an age where technology and innovation are driving progress in every industry. Jobs that didn't exist ten years ago are now in high demand, and many of them require a strong foundation in STEM. By providing students with a STEM education, we are preparing them for the jobs of tomorrow, ensuring that they have the skills they need to succeed in a rapidly changing world.

Furthermore, STEM education has the potential to address some of the biggest challenges facing our planet. Climate change, renewable energy, and sustainable agriculture are just a few examples of issues that can be addressed through STEM. By fostering a love of science and technology in our students, we are creating a generation of problem-solvers who can help tackle these challenges and make the world a better place.

Finally, STEM education is important because it promotes diversity and equity. Historically, underrepresented groups, such as women and minorities, have been excluded from STEM fields. By providing STEM education to all students, regardless of their gender or ethnicity, we are leveling the playing field and creating opportunities for everyone to succeed. This is critical if we want to build a more just and equitable society.

How to Implement STEM Education

Implementing STEM Education in Early Childhood

To implement STEM education in early childhood, it is important to consider the following:

1. ***Start with children's natural curiosity and interests***

   Children have a natural curiosity and desire to learn about the world around them. By tapping into their interests, educators can create engaging STEM experiences that build on their prior knowledge and promote the development of new skills and concepts.

2. ***Incorporate hands-on, experiential learning***

   Young children learn best through hands-on, experiential learning opportunities. STEM education provides a unique opportunity to engage children in activities that allow them to explore, experiment, and discover through inquiry-based learning.

3. ***Encourage collaboration and communication***

   STEM education provides opportunities for children to collaborate with peers, share ideas, and communicate their thinking. By working together, children can build on their own knowledge and experiences and develop important social skills such as teamwork, communication, and problem-solving.

4. ***Emphasize the process over the product***

   STEM education, the process of exploration, inquiry, and problem-solving is often more important than the end product. Emphasizing the process allows children to focus on learning and developing new skills, rather than on creating a perfect final product.

5. ***Integrate technology into STEM learning***

Technology can be a valuable tool in STEM education, providing opportunities for children to learn about coding, robotics, and other important STEM concepts. However, it is important to remember that technology should be used as a tool to support learning, rather than as a replacement for hands-on experiences and human interaction.

Rationale behind the expansions of STEM to STEAM and STREAM

Incorporating the Arts in STEM: STEAM

The "A" in STEAM stands for art, which has been added to the traditional STEM subjects (science, technology, engineering, and math) in recent years. The

inclusion of art recognizes its importance in shaping the creative and innovative thinking of students, and its role in creating a well-rounded education. However, the exact meaning of "art" in STEAM has been a point of confusion and disagreement within the academic community. Four main definitions have been identified: non-STEM, visual art, arts education, and pedagogical practices. Despite the prevalence of the arts education definition, there is still a lack of clarity on what the arts in STEAM are supposed to encompass. This lack of agreement on the definition of the arts in STEAM makes it difficult for teachers to implement STEAM learning in their classrooms.

Arts in the STEM classroom

Initially, educators created the STEM acronym to emphasize the importance of these subjects. Since introducing STEAM rather than STEM, there has also been a shift in how the acronym is viewed. Now, the focus is on how the subjects work together, rather than a discussion of the importance each subject has on its own. With this shift, STEM subjects view the arts in STEAM as a tool to further their own subjects. STEM background articles often discuss topics such as the soft skills like creativity and collaboration as a reason for why the arts should be used in their classrooms, rather than presenting the merit in taking arts classes, even for STEM students. STEM subjects often use STEAM to argue for a specific pedagogical approach, as is described in an article from an engineering perspective that uses STEAM to make the case for project-based learning over lecture-based within the engineering field.

The arts are often viewed as a path to attracting those who do not feel represented in STEM subjects. For instance, robotics events and competitions are often brought up as a way to attract girls to STEM subjects, as they offer the chance to be more creative beyond just learning programming. While there may be an issue of representation within the STEM subjects, and it is incredibly beneficial to figure out ways for people who are not usually represented to be more involved in these subjects, the arts have more to offer.

1) **Importance of STEAM**

STEAM type of education in schools provides children opportunities to learn creatively, making use of various 21st-century skills. These general skills are important for creating a future-ready workforce that clearly understands the potential of questioning while solving real-life problems.

The value of a STEAM education

Regardless of the exact approach taken, each of the disciplines within STEAM has something to offer to every student. For educators in both the arts and the STEM subjects, it is useful to remember that there is something to be learned from other disciplines, and at the same time, each discipline has something to offer on its own. Often, the arts are taken for granted, with a focus on arts pedagogy, or other skills learned rather than the inherent value of an art education. But within the arts, it can also be difficult to see how the STEM subjects can fit in. However, there are only more opportunities being made to incorporate these ideas into an arts education. One of the wonderful things about art is that it has no limit, and adding new ideas and approaches can only lead to an increase in the new and unique perspectives that we see within art itself.

John Maeda, the former president of the Rhode Island School of Design, spoke passionately and wonderfully on his own experience with STEAM, and the value it has added to his own life. If you have an extra hour and a half to spare, it's a fantastic argument for STEAM education.

2) **What Are the Practical Applications of STEAM?**

Inspirational collaborators and educators, like scientist Vanessa Pirotta, mathematician Eddie Woo, bio-engineer Melissa Knothe Tate, show us how adding 'a' in STEM works in the real world. There are so many hands-on learning opportunities coming up in institutes and schools, which are usually called "maker spaces". They use science and other resources like embedded video, soft circuits, data arts, game creation, and many more to encourage collaboration in discovery and learning.

How should STEAM be implemented?

The National Education Policy highlighted the importance of bridging the science-arts gap. It falls in line with STEAM or the integration of the arts into traditional STEM (Science, Technology, Engineering and Maths) education. While it is heartening to see growing acceptance towards STEAM in India, there is still a misconception that the arts serve as a distraction, or take away from the seriousness of science education.

When the concept picked up in 2015, a US-based publication made an important distinction: STEAM is not about spending less time on science to make room for the arts; it is about bringing these two disciplines together and looking at things in a new way. Many students on the brink of college or starting work spend a lot of time worrying about how they will choose between two "conflicting" interests of science and art. That, more than anything else, is where STEAM education changes the game. It doesn't dilute your experience with science or alienate you from it while you take up the arts. It is a people-focused approach to career-building, one where you can tailor your career path to suit your unique interests without leaving one behind in favor of another.

As a musician and educator, art is an integral part of my day. My background in law also gives me a better understanding of entertainment contracts that come our way. As an entrepreneur, I have to think about numbers, growth, feasibility, and scaling. I'm not the only one whose day involves taking charge of creative processes while also having to build new technical skills.

Perignat and Katz-Buonincontro also identified and defined different implementation models for merging the STEAM subjects: trans-disciplinary, inter-disciplinary, multi-disciplinary, cross-disciplinary, and arts-integration. Trans-disciplinary refers to disciplines that are fully merged without lines differentiating them. Inter-disciplinary refers to bringing disciplines together under a theme, but allowing each to remain

distinct. Multi-disciplinary refers to collaboration among the disciplines without any merging. Cross-disciplinary refers to looking at one discipline through the lens of another discipline. Arts-integration refers to using arts projects or ideas in the other disciplines.

Once again, there is still disagreement around what the implementation of STEAM looks like. Continuing to use this framework, the literature review found that arts-integration was the most frequent, followed closely by interdisciplinary. Similar to ideas surrounding the definition of the arts in STEAM, there is a diversity of opinions on how to put STEAM into practice within a classroom. Often, articles don't address this issue. Many articles refer to their thoughts on the implementation of STEAM not as an opinion, but rather as the only course of action. However, there is clearly some disagreement about the best way to work across or between the disciplines in STEAM. Once again, without a unified definition of what it means to implement STEAM, it is difficult to see how it can be used in a classroom.

Adding reading and literacy to STEM: STREAM

STREAM adds another layer to STEAM, which is Reading. Advocates of STREAM believe that literacy is an important part of a well-rounded curriculum, since it requires creativity and critical thinking. Projects in STREAM are similar to those in STEAM and STEM, but it includes components of writing and reading.

STREAM incorporates another layer to STEM and STEAM by adding 'Reading' into the equation. Reading or literacy promotes critical thinking and creativity. By introducing reading as a core element of discovering new knowledge, STREAM provides a well-rounded learning experience.

Challenges and the future of STEM, STEAM and STREAM

STEM education has gained increasing attention in recent years as educators strive to find more effective ways to engage and connect with students. While STEM has been around for some time, it has gained renewed emphasis as educators and policymakers highlight the need for more robust education in science, technology, engineering, and mathematics. However, despite its growing popularity, STEM education still faces a range of challenges that need to be addressed in order to make it more accessible, inclusive, and effective.

One of the biggest challenges facing STEM education is the lack of resources available for teachers and students. Schools often struggle to provide funding for the latest technology and training for teachers on how to use them effectively as learning tools. This can make it difficult for teachers to create engaging lesson plans that foster creativity, problem-solving skills, critical thinking, and innovation. Furthermore, the focus on grades and assessments, rather than the development of these important skills, can hinder the effectiveness of STEM education.

Another challenge is that many teachers are simply not interested in teaching STEM. They may prefer to keep each subject isolated and taught separately rather than integrating them into a more interdisciplinary approach. This can make it difficult for students to see the connections between different subjects and understand how they are related to real-world applications.

Despite these challenges, STEM education is crucial to the development of every child. With the increasing influence of digital technology in our daily lives, children are constantly exposed to STEM concepts, making it essential to educate them on how to use technology effectively and foster a love of learning in these fields. STEM education should be integrated into the curriculum from an early age to develop skills that are important for future success.

One way to make STEM education more accessible and inclusive is to expand it to include the arts and humanities, creating STEAM and STREAM programs. This approach can encourage students to develop empathy and use their knowledge and skills for the better good. Arts and humanities also encourage creativity and innovation, essential for navigating today's rapidly changing world. By incorporating these subjects into STEM education, learning becomes more engaging and exciting, boosting students' intrinsic motivation and connecting them with each other through shared experiences.

Furthermore, STEAM and STREAM programs provide a more well-rounded education that is crucial for the development of overall well-being, particularly for young children. The challenges of tomorrow are complex and unpredictable, and interdisciplinary knowledge and skills, as well as the capacity to work together, are necessary for future success. The integration of humanities and literacy with STEM studies provides the foundation necessary for learners to thrive in life.

Conclusion

In conclusion, STEM education has become an essential pillar of modern education, focusing on science, technology, engineering, and mathematics. It aims to equip students with critical thinking, problem-solving, and innovation skills needed to thrive in the 21st century. Over time, the acronym has expanded to include the arts, leading to the emergence of STEAM and STREAM programs.

STEAM recognizes the significance of art in fostering creativity and innovative thinking, enriching students' learning experiences. By integrating art into STEM subjects, educators aim to create a holistic and cohesive approach to education. However, the implementation of STEAM can vary, and there is a need for further clarity to effectively apply it in classrooms.

STREAM further extends the acronym by incorporating reading and literacy, acknowledging their role in developing critical thinking and creativity. These interdisciplinary programs emphasize collaboration, communication, and hands-on learning, preparing students for a rapidly evolving workforce.

STEM education's importance lies in cultivating the four Cs: critical thinking, communication, collaboration, and creativity. By focusing on these

skills, students are better prepared for the challenges of the modern world and have the tools to succeed in diverse career paths.

Implementing STEM education in early childhood is essential, starting with nurturing children's natural curiosity and incorporating hands-on, experiential learning opportunities. Encouraging collaboration and communication helps build essential social skills, and technology can be utilized to support learning.

Despite its significance, STEM education faces challenges, such as the lack of resources and teachers' resistance to integrating subjects. However, the integration of arts and humanities in STEAM and STREAM programs can make STEM education more accessible, inclusive, and well-rounded.

In conclusion, STEM education is a vital foundation for students, empowering them to become critical thinkers, problem solvers, and innovators, equipped to tackle the challenges of the future and contribute positively to society. By embracing interdisciplinary approaches like STEAM and STREAM, we can create well-rounded and future-ready learners who will shape a better world.

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