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Strengthening STEM Education with Teacher Education: Preparing Teachers for STEM Teaching in the Twenty-First Century

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Abstract

For students to learn in the STEM fields, teachers must foster an environment of guided investigation. To encourage students to study and to better equip them to comprehend and address real-world challenges, it is essential to advance an integrated approach to STEM education that incorporates real-life scenarios. By utilizing concepts that cut across disciplines and the skills of critical thinking, cooperation, and creativity, STEM education can assist the next generation of students in solving real-world challenges. The way teachers may create learning environments that support students in developing their 21st-century skills is an example of how STEM is being implemented. An extensive rethinking and restructuring of pre-service courses and in-service workshops would be required for proper preparation in integrated STEM. Findings offer a starting point for identifying teacher needs in integrated STEM.

Keywords: *STEM, STEM Education, Teacher Education, Professional Development.*

Introduction

Progress in education drives industry growth around the world, and industry growth compels changes in education. On a global scale, among the most crucial concerns are those related to industry, technology, and education because of their close connections (ASLAN EFE & Hanas, 2022). The 21st-century skills, which are also known as skills for our age, are demanded of every person, hence educational practices must be created to support the development of these talents (ASLAN EFE & Hanas, 2022). For several reasons, including cultural and economic progress, increasing participation rates in STEM education has emerged as a global need (Delahunty et al., 2021). To prepare people for the demands of the evolving workforce, STEM education has been implemented on a global scale (ASLAN EFE & Hanas, 2022). The availability of a multitude of skilled and well-trained personnel in the natural sciences, technology, engineering, and mathematics (STEM) sphere is essential for nations to continue being globally viable and competitive (Hackman et al., 2021).

The goal of integrated STEM education is to bring together the numerous academic fields to discuss a single issue that is relevant to the real world (Delahunty et al., 2021). Effective STEM educators are necessary in the context of the national emphasis on enhancing STEM education. Incoming educators need to get quality pre-service STEM teaching instruction, but this need is frequently disregarded (Radloff & Guzey, 2016). STEM education has been adopted in many

nations and is seen as significant (L. T. B. Le et al., 2021). Teachers frequently believe that they must modify their current teaching philosophies in order to successfully integrate STEM education (L. T. B. Le et al., 2021). In schools and institutions, STEM education which combines the four disciplines has been encouraged (Hoon et al., 2022). Only when students are inspired to study these topics will there be a surge in the number of workers in science and technology businesses (Hackman et al., 2021). An excellent strategy to boost students' motivation and enthusiasm for studying the STEM fields is STEM education (Hackman et al., 2021).

Science, Technology, Engineering, and Mathematics (STEM) components are increasingly and deeply ingrained in university-level courses in the twenty-first century, making teaching more difficult and complex. To create the university's desired outcome, the STEM workforce, the incorporation of STEM has necessitated changes to the course materials and method of instruction (Hoon et al., 2022). A passion for STEM education promotes the development and use of scientific knowledge to solve societal issues and boost the economy (Algarni & Alahmad, 2021). In terms of using engineering, they advise enhancing professional development programs. As a result, science will be learned that goes beyond basic engineering frameworks and notions (Algarni & Alahmad, 2021).

Understanding the concept of STEM (Science, Technology, Engineering, and Mathematics)

In many nations, STEM education is seen as the cornerstone of economic development. It has drawn a lot of interest from many educational systems, but its actual application has created several issues (L. T. B. Le et al., 2021). In terms of fostering a STEM culture and climate and building the link between the school, society, and business world, instructors who implement STEM in scientific education over time have higher averages (ASLAN EFE & Hanas, 2022).

Science, Technology, Engineering, and Mathematics are referred to as STEM. STEM education has been defined as an interdisciplinary approach to education that tries to bring disparate fields of study together to aid students in solving real-world challenges (L. T. B. Le et al., 2021). STEM (science, technology, engineering, and math) education is thought to be one of the keys to overcoming many of our current difficulties. By piquing students' interest in STEM fields, STEM education is beneficial to the students. To accomplish this difficult goal, everyone must work together to create and innovate classroom practices for maths teachers (Noor Anita et al., 2019). The 21st-century teaching techniques, instructional designs, and STEM implementation were all part of the STEM practices. Creativity, data literacy, digital

literacy, and computer science are among the basic competencies that cover 21st-century teaching skills. Critical thinking, communication, cooperation, and problem-solving abilities were shown to be the most prevalent practices (Noor Anita et al., 2019). The instructors were able to apply the STEM method since common practices in the delivery of mathematics instruction were identified, enabling them to be both physically and intellectually ready. The instructional designs included scaffolding, evaluation, cultural relevance, and sensitivity in addition to the integration of STEM subjects and real-world applications (Noor Anita et al., 2019). Future generations will need to have advanced knowledge, abilities, and capabilities in technology to meet the challenges of the fourth industrial revolution (4IR). As 4IR grows, a nation's competitiveness depends on its STEM human capital (Rahman et al., 2021).

STEM and Students' Learning Outcomes

STEM (Science, Technology, Engineering, and Mathematics) education plays a crucial role in developing essential skills and knowledge for students, preparing them for a technology-driven world. It enhances problem-solving abilities by encouraging students to approach complex problems methodically and apply logic and reasoning to find solutions. STEM education also fosters critical thinking, as students learn to question assumptions, analyse data, and evaluate evidence, making them more adept at assessing various situations. The hands-on, project-based nature of STEM often leads to increased engagement and motivation, which can result in improved academic performance. While STEM project-based learning activities outside of the classroom catered exclusively to kids' interests in STEM careers, STEM project-based learning activities within the science curriculum focused on enhancing students' learning achievement and higher-order thinking skills. Lastly, we make a few recommendations for future research areas in the area of integrated STEM approaches and student learning outcomes (H. C. Le et al., 2023). Through the progression of activities in STEM lessons, students acquire 21st-century skills such as reasoning, critical thinking, teamwork, time management, problem-solving, and the ability to search and select information. Students also learn how science, engineering, and technology integrate with mathematics, physics, and other subjects to solve real-world problems (Tuong et al., 2023).

Additionally, STEM emphasizes the application of theoretical knowledge to real-world scenarios, making education more relevant and practical. Collaboration and teamwork are integral to STEM, teaching students' effective communication and cooperative skills. Creativity and innovation are encouraged, enabling students to think outside the box and develop new solutions. With the growing demand for STEM skills in the job market, students

who receive a strong STEM education are better prepared for future careers in fields like engineering, technology, and medicine. The STEM profile that goes with it communicates and graphically portrays the advantages and disadvantages of design principles, explaining the degrees of students' fruitful interdisciplinary interaction. STEM education will find the STEM protocol useful as a research tool, and STEM classroom teachers will find it useful as a pedagogical guide to help them create better STEM learning experiences (Ong et al., 2024). Furthermore, STEM education enhances digital literacy, equipping students with the tools to navigate the digital world. Through the iterative process of STEM projects, students also develop resilience and adaptability, learning that failure is a part of the learning process and that adapting their approaches is key to success. Overall, STEM education significantly enhances student learning outcomes, equipping them with the skills necessary to thrive in an evolving world.

STEM and Teacher Education

The world's top STEM (Science, Technology, Engineering, and Mathematics) professionals are to be educated, according to one of the four objectives of STEM. Professional development courses emphasize developing instructors' capacities and giving them direction on how to teach (Sujeewa Vijayanthi Polgampala, 2017). STEM implementation can be seen in the way teachers are able to set up learning environments that help pupils develop their 21st-century capabilities (Hoon et al., 2022). It has been proposed that a method that boosts student enthusiasm and engagement is integrated STEM education, which is hailed as a potential paradigm for the successful acquisition of 21st-century STEM competencies (Delahunty et al., 2021). The success rates of teachers in fostering a STEM-focused culture and atmosphere in classrooms are better when they have previously participated in projects connected to STEM education (ASLAN EFE & Hanas, 2022). Students' interest in STEM education will be stimulated by teachers who are experts in the field (Rahman et al., 2021).

Teachers encountered numerous difficulties with their interdisciplinary expertise, instructional strategies, curricula, practical limitations, and ideas about effective STEM education (L. T. B. Le et al., 2021). Since teachers lack experience and are ineffective in teaching science, technology, engineering, and mathematics (STEM), pupils receive inadequate instruction and lack the motivation to pursue STEM occupations (Hackman et al., 2021). (Yıldırım & Türk, 2018) emphasized that a successful STEM teacher should possess STEM knowledge as well as knowledge of pedagogy, integration, context, and 21st-century abilities. In particular, STEM subject knowledge, pedagogic knowledge, 21st-century skill knowledge, and integration

knowledge have been widely highlighted when the body of literature has been studied (Yıldırım & Türk, 2018). The benefits of possessing STEM knowledge and related abilities enable teachers to use effective teaching strategies. On the other hand, children who are STEM-literate can be creative, and innovative, and integrate STEM to grasp the issue and solve it by applying it to the context of the real world (Rahman et al., 2021). Secondary school pupils who participate in STEM-related activities are adequately prepared for future professions in the STEM workforce (Rahman et al., 2021). The effective teaching of STEM requires positive teacher attitudes (Hackman et al., 2021). In a study, all of the teachers thought they lacked STEM expertise. According to them, STEM integration required a multidisciplinary understanding of Science, Technology, Engineering, and Math, whereas they were trained to teach a particular topic domain, such as Physics, Math, or Chemistry. They believed that their interdisciplinary expertise needed to be improved for them to plan and execute successful STEM lessons (L. T. B. Le et al., 2021). The teachers believed that their motivation to teach STEM was based on their personal desire for innovative teaching strategies. The teachers claimed that the STEM movement in education was a new one that required them to be proficient in both cutting-edge subject knowledge and instructional strategies (L. T. B. Le et al., 2021). Teachers have admitted that they feel lacking in their understanding of engineering, application, and science and technology (Yıldırım & Türk, 2018).

STEM has transformed attitudes and ideas towards teaching mathematics and has come to view it as integral and indivisible (Alkhateeb, 2018). Few teachers had clear and right opinions about using STEM to create a helpful learning environment for students to enhance their talents. Furthermore, students' academic performance and success suffered significantly from teachers' lack of STEM teaching experience (Alkhateeb, 2018). STEM educators need to have a variety of approaches at their disposal for explaining STEM concepts, directing students in scientific inquiry, and encouraging more instructors to become involved in STEM education by allaying their concerns (Sujeewa Vijayanthi Polgampala, 2017). To address the present needs of the teacher, there should be a strong emphasis on in-service programs and the provision of specialized training for subject knowledge, pedagogy, and classroom management (Sujeewa Vijayanthi Polgampala, 2017). It is crucial to equip educators with the necessary tools for successful K–12 integrated STEM learning experiences and to provide them with ongoing, high-quality professional development. Policies for pre-service and in-service teacher preparation that support integrated, sustained STEM instruction can be very important in this regard (Kozan et al., 2023).

Teachers Professional Development of Teachers and STEM Education: Pre-service and In-service Education for Future Teachers

The academic integration of STEM education was considered to be sufficient by science teachers, who also emphasized the need to address the lack of collaboration between the corporate world, society, and schools which is crucial to a successful STEM education. asserted that the STEM climate and culture in schools are insufficient (ASLAN EFE & Hanas, 2022). It is extremely difficult for teachers to execute an integrated approach to STEM education with real-life scenarios that will both inspire kids to learn and better prepare them for issues they will face in the real world (Costa et al., 2022). The application of this understanding in instructional design and deliberate reflection on pedagogical decisions by teachers must also be supported and encouraged (Marco-Bujosa, 2021).

Though experience was regarded as having a lower degree of proficiency than preparedness and effort, it was found to be strongly connected with pre-service teachers' confidence in STEM practices (Hoon et al., 2022). Science, technology, engineering, and math are all included in STEM education. The early childhood era and aspects of STEM education, such as inquiry, exploration, observation, communication, and play, are closely related (Çiftçi et al., 2022). Early childhood educators should give priority to integrating STEM education into the early childhood curriculum to support kids in learning about STEM subjects and concepts during this era of rapid learning and growth (Çiftçi et al., 2022).

Since the majority of pre-service teachers agreed that STEM education is appropriate for early childhood education, STEM education should be implemented during this time (Çiftçi et al., 2022). Pre-service STEM teacher education should at the very least cover STEM curriculum, methodology, and conceptualization (Radloff & Guzey, 2016). Professional development programs for in-service teachers should place more emphasis on providing teachers with current STEM knowledge and pedagogical techniques so that teachers will feel more competent and well-prepared to teach STEM (L. T. B. Le et al., 2021). Additionally, in-service teacher professional learning and development designers and trainers must equip teachers with the ability to deal with challenges and modify their current teaching strategies to fit STEM education for their classrooms and students (L. T. B. Le et al., 2021). The study recommends paying more attention to teachers' training on STEM skills to be able to provide such supportive classroom environments that support students' mathematical skills because the importance of providing supportive learning environments to students to be able to employ STEM is largely dependent on teachers' thoughtful planning of lessons (Alkhateeb, 2018).

STEM training, peer collaboration, professional and administrative support, and classroom time all have a favorable impact on science teachers' views toward STEM education (Hackman et al., 2021). It is important for teacher candidates to have the chance to design and execute research-based pedagogies, as well as to learn about the significance of education research for their own teaching practices (Milner-Bolotin, 2018). It is obvious that teacher professional development programs that can improve teachers' attitudes will benefit the adoption of integrated STEM teaching strategies (Delahunty et al., 2021).

Critical thinking, collaboration, communication, problem-solving, research-based pedagogy, problem-based and project-based learning, technological integration, accessibility, professional development and learning support, effectiveness evidence, availability of resources and practitioner support, and scalability were the dominant STEM practices. Despite the absence of research on integrated STEM domains, maths teachers should decide which STEM practices to use. The younger generation may be able to fill the increasing demand for STEM-related occupations once more students show an interest in investigating and delving into the sector (Noor Anita et al., 2019). For the purpose of IST and PST professional growth, training opportunities should be made available for acquiring ICT integration knowledge. Teachers ought to keep their knowledge current and maintain their digital and scientific literacy (Noor Anita et al., 2019).

Teachers understood the value of receiving training in STEM education, felt that this kind of professional development was highly pertinent, and found it to have increased their understanding of and ability to use STEM hands-on practices in the classroom (Costa et al., 2022). It is feasible to adopt a specialised online PDP in STEM education that inspires educators and enhances their expertise in putting STEM-related practical lessons into practise in the classroom. Teachers also understand the significance of using relevant real-world examples since it motivates students to study (Costa et al., 2022). The teachers made it clear that they did not feel prepared enough to teach STEM subjects. Teachers also emphasized the need for STEM understanding, pedagogy expertise, and 21st-century skills in a competent STEM teacher (Yıldırım & Türk, 2018). (Yıldırım & Türk, 2018) stress that STEM education is a valuable educational idea, but that there might be issues that come up in STEM education. Additionally, it was shown that instructors' attitudes towards engineering and technology have improved as a result of the STEM training.

STEM teacher preparation programs and professional development are what propel STEM education forward. Eliminating instructors' misconceptions and technological fear, which were the main obstacles, is especially important (Sujeewa Vijayanthi Polgampala, 2017).

Including technology in your regular lessons, there is still a high demand for STEM instructors who have received specialized training and are knowledgeable about interactive inquiry-based teaching methods, rigorous curricula, and acceptable knowledge evaluation procedures. By adding engineering standards to the current science standards, policymakers and professionals promote STEM education (Sujeewa Vijayanthi Polgampala, 2017). The STEM-focused professional development that prioritized career awareness, inquiry-based activities, and multidisciplinary activities was of particular interest to instructors. The most popular delivery methods were in-person meetings, workshops, and tours. It is necessary to raise awareness among parents and students of the value of STEM education (Sujeewa Vijayanthi Polgampala, 2017). Pre-service courses and in-service workshops would need to be extensively redesigned if students were to receive proper training in integrated STEM. Findings give a place to start in identifying teacher needs for integrated STEM (Shernoff et al., 2017).

Conclusion

For the purpose of educating people who can fulfil the demands of the evolving workforce, STEM education has been adopted globally. To encourage students' learning in STEM disciplines, teachers must establish a guided discovery atmosphere. To encourage pupils to study and better prepare them to comprehend and resolve real-world problems, it is imperative to promote an integrated approach to STEM education with realistic scenarios. It is urgently important to comprehend the difficulties and barriers that arise when creating and implementing integrated STEM curricula and instruction, given the growing interest in and importance of such approaches to STEM education. The focus on STEM-focused professional development, emphasizing career awareness, inquiry-based activities, and multidisciplinary approaches, has garnered significant interest among instructors. Delivery methods such as in-person meetings, workshops, and tours have been particularly popular. However, there's a need to enhance awareness among parents and students regarding the value of STEM education. Both pre-service courses and in-service workshops require substantial redesigning to adequately equip students with integrated STEM training. These findings provide a foundational understanding for identifying teacher needs in the realm of integrated STEM education.

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