



Effective Teacher Training on STEM and How it Affects Students' Academic Performance

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ABSTRACT

In the 21st century, the demand for scientifically literate individuals with high-level cognitive and problem-solving skills has made STEM (Science, Technology, Engineering, and Mathematics) education a critical priority for global development. The effectiveness of STEM education is largely determined by the quality and preparedness of teachers, making teacher training a fundamental component in achieving improved student outcomes. This paper examined the role of effective teacher training in enhancing STEM instruction and its direct impact on student academic performance. It highlights that STEM teacher training equips educators with pedagogical tools, interdisciplinary approaches, and real-world applications that enhance students' engagement, critical thinking, and academic success. Studies have shown that students taught by well-trained STEM educators exhibit higher comprehension levels, increased motivation, and better performance in assessments. Furthermore, trained teachers are better able to foster inclusive learning environments, support underrepresented groups, and prepare students for future STEM careers. The paper concludes that investing in continuous and practical STEM teacher training is essential for improving educational outcomes and building a competent STEM workforce for future societal needs.

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INTRODUCTION

In the 21st century, it has become significant for every country to raise individuals who are scientifically literate, who can keep up with the changing information and technology, who will respond to the needs of the education and business world, and who have high-level of cognitive skills. Along with the rapid development of information and communication technologies, 21st century skills have become different from 20th century skills (Kazu & Yalcin, 2021). Therefore, the change in expectations of individuals in 21st century has required to take necessary measures in parallel with this change in educational goals. In the necessity of increasing the quality standards of education, students are

required to have the skills to solve their daily problems and contribute to the needs of society.

Science, Technology, Engineering, and Mathematics (STEM) education is increasingly recognized as a critical driver of innovation and economic growth in the 21st century. However, the success of STEM education largely depends on the capacity and competence of teachers to effectively deliver these subjects. Teacher training, especially when aligned with modern pedagogical approaches and technological integration, plays a significant role in shaping students' interest, engagement, and achievement in STEM disciplines. Teachers' role is inevitable in the easy adaptation of innovations such as STEM to the education system and in overcoming the problems encountered. Teachers' perceptions

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and preparedness really affect the success of the implementation of STEM education. They need to have adequate prior training and understanding in order to teach STEM activities to their students (Tunc & Bagceci, 2021).

STEM Education

Recent advances in information and communication technology continue to affect each aspect of society, along with important implications in the field of education. Countries aiming to be a leader in the scientific and technological race also attach great importance to science and mathematics education (Kazu & Yalcin, 2021). For this reason, in order not to fall behind in the technological race, they have adopted the basic aim of raising individuals who understand science and mathematics conceptually well, associate these concepts with daily events, and can solve the problems they face in daily life with the information transferred in schools (Çepni, 2017).

Dinçer (2014) argues that the basic resource of the economy is individuals who can produce knowledge and use them when necessary. For this reason, it is of great importance to educate the new generation with skills such as analytical, creative, and critical thinking, which are called 21st century skills. The way to gain these skills is through "STEM", in other words, science, technology, engineering, and mathematics which is the basis of today's and future science and technological developments. STEM education, a workforce consisting of individuals who are aware of STEM literacy, aims to continue their current work in the STEM field, to produce innovations that will provide an economic advantage to countries, and to be competent in future business areas (Thomas, 2014).

STEM education is designed to foster a deep understanding of how science and technology intersect with everyday life and industry. It emphasizes hands-on learning, project-based activities, and collaboration to develop students' ability to tackle real-world challenges. This approach not only prepares students for STEM-related careers but also builds essential skills such as adaptability, teamwork,

and analytical thinking valuable across any profession.

The STEM program is an educational initiative that introduces students to an integrated curriculum combining science, technology, engineering, and mathematics. Many schools and organizations offer specialized STEM programs that provide students with opportunities for hands-on experiences, mentorship, and exposure to real-world STEM careers. These programs exist at various educational levels, from elementary school to college, and include summer camps, scholarships, and competitions that encourage students to explore STEM fields (Zoloth, 2025). STEM programs often focus on inquiry-based learning, where students engage in problem-solving through experimentation and practical application. This method helps develop a deeper knowledge of concepts rather than rote memorization, leading to better retention and a greater appreciation for how STEM impacts the world. In some schools, students can participate in robotics clubs, science fairs, and coding boot camps, all of which can prepare them for future careers. High school students may also have access to dual-enrollment programs and summer STEM programs, allowing them to take college-level STEM courses before graduation, giving them a head start in higher education.

William (2011) defines STEM education as an approach that supports student participation using engineering and technology and improves students' learning in science and mathematics. In addition, Israel, Maynard, and Williamson (2013) describe it as student centered and collaborative learning beyond the contexts of four STEM domains. STEM education is an approach that eliminates the boundaries between disciplines by enabling students to understand the world as a whole rather than parts (Lantz, 2009). Although there is no consensus on the exact definition of STEM education (Thomas, 2014), the general belief is that STEM involves military, economic, high-level thinking that brings together disciplines, leads to effective and qualified learning, takes existing knowledge, and puts it into daily life (Yıldırım & Altun, 2015). According to Şahin et al. (2014), STEM education aims to enable

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individuals to look at problems from a different perspective between fields by gaining skills and knowledge with a totalitarian approach to education.

The STEM curriculum includes moving beyond the four walls of the classroom by incorporating informal learning and continuously expanding learning methods. It is based on combining formal and informal activities, such as mobile device use or museum visits, and it improves learners' interest in learning and increases their participation (Wang & Chiang, 2020). The significance of STEM fields and the critical need to increase those entering the STEM workforce has accelerated the push to attract more students into STEM fields, especially those who are from underrepresented populations in STEM (Alfred, Ray & Johnson, 2019).

Importance of STEM Education in the 21st Century

With STEM (Science, Technology, Engineering, and Mathematics), it is not the teaching of one subject but rather the amalgamation of all four subjects as a comprehensive one through an interdisciplinary curriculum. This helps students to deal with real-world situations and apply their learnings to create, innovate and discover new things. Also, it has been proven that students who adopt the STEM learning approach have better possibilities of getting placed at good companies, achieving the goals of their life contributing to the environment, etc (Ayushi, 2025).

Benefits of STEM Education

The following are the Benefits of STEM education:

1. Enhance Critical Thinking: STEM education is a very important aspect of student's life as it teaches them to solve problems effectively. Students who are accustomed to STEM education at an early age learn to analyze challenges and are able to develop strategies to tackle them.
2. Motivates Experimenting: In the last couple of decades, it has been noticed that STEM education provides a healthy environment

and encourages students to try new things. Children who are part of STEM education learn the importance of failure and how to tackle it without getting affected.

3. Teamwork: STEM education is best for team-building activities and it helps students from every level to work together. They come together and find solutions to the problem discuss with each other, record data, give presentations, write reports, etc. In the end, they come to know the importance of working with each other and, flourish in a complete team-building environment.
4. Boosts Curiosity: This is one of the most vital features of STEM education. Students who are made habitual of this type of education since childhood, develop curiosity and innovation as their regular habits. This type of education enhances the critical way of thinking and empowers them to ask questions.
5. Enhances Problem Solving Skills: With the enhancement of critical thinking, students also learn problem-solving skills. By adapting STEM education from an early age children learn the ways of examining problems. Children can also create amazing plans to solve problems. Also, it helps students to look at the bigger picture and not from the smaller aspect.

From the above, in order to attract more students is to increase students' interest and achievement in the STEM subjects and this can be achieved only through effective teacher training.

Teacher Training

Teacher training is a process of getting the required skills by a teacher for a particular subject. The training is a valuable practice for the teachers to enhanced their teaching skills. A trained teacher has more skills and techniques to be applied for the better academic achievements of learners (Ulla, 2018). A teacher having better teaching skills can also produce students' interest in a particular subject (Giovazolias et al., 2019). Many researchers including (Oliveira et al., 2019)



stated the importance of teachers training. The teacher's training provides the solutions of educational problems (Schütze et al., 2017).

Teacher training can be an effective way of imparting knowledge, skills, and motivation to teachers. It is a way to provide continuous education to the teachers who have already taken any certification in teaching and have chosen teaching as a profession. Teacher training can be defined as a series of activities, arranged to engage teachers to enhance their knowledge, raise their skills, and broaden their professional approaches (Koellner & Greenblatt, 2018). These trainings usually focus on the development of change in a teacher in a form of knowledge, satisfaction, motivation, and professional growth. As a teacher plays a vital role in the process of education, teacher motivation can directly influence the process of learning. Therefore, it is important that a teacher be motivated. Teacher training programs are very important to maintain the teachers' motivation and their professional development (Gorozidis & Papaioannou, 2014).

In this modern age, the teacher's training is an important requirement and essential component for all the educational activities including conducive learning environment, curriculum development and implementation and assessment (Zulfikar, 2016). A trained and skilful teacher has more ability to teach the students and implement the various teaching methods successfully (Saira et al., 2021). When teachers apply the various teaching methods and techniques according to the acquired skills then students achieved higher academic results and the interest of the student is also increased (Wuryaningsih et al., 2019).

A teacher training program is a program that equips teachers with techniques and modern pedagogy strategies that helps them to better connect with, manage, and teach to their students in a manner which ensures that all students are learning and benefitting. Teacher training programs are of different types and forms: There are short term, medium term and long-term programs which are conducted online or offline. The teacher needs to understand from the perspective of the student as to what would make

a classroom session significantly more intriguing. Every training course designed for teachers offers practical classroom sessions as an integral part of the course, with each candidate being mentored for making the classroom teaching sessions more engaging and interesting for the benefit of the students.

Benefits of Teacher Training

1. Professional growth: When teachers attend training programs, it gives them the opportunity for continuous professional development – to learn new ways, methods, strategies, skills and tools. When teachers get upskilled they automatically feel confident, happy and motivated to achieve greater things with their students.
2. Better student management: As a teacher it is important to know, understand and analyze students effectively. Only then can they know how to teach their students. Teacher training programs help teachers to better understand and therefore, better manage their students.
3. Impacts students indirectly: A teacher training program not just impacts teachers but also students. A single teacher who is upskilled can go on to impact thousands of students. Teachers have a big role to play in nation building because students are the citizens of tomorrow.

It is also important to not only train new teachers, but also continued training for teachers who have been working for a long time. Even the best teachers will begin to lag behind if they don't continue to strive for excellence. The reason why continuing teacher training is so important for educational excellence is simple: teachers need to be given regular training opportunities in order to stay at the top of their game. Teacher training gives the teacher a theoretical and practical education on the nuances of teaching students how to accomplish their greatest potential. Without this training, the teachers will not be in a position to provide proper guidance, and that will affect the foundation of the education being built.



Student Academic Performance

Academic performance is crucial in shaping a student's future, reflecting not just their current learning but also their long-term educational goals. It encompasses grades, GPA, and degrees, with a strong emphasis on exam scores and continuous evaluations. Academic performance definition by authors may be different but it refers to how well students do in their educational pursuits, primarily measured through grades, test scores, and overall comprehension of academic material. According to Tadese, Yeshaneh and Mulu (2022) academic performance/ achievement is the extent to which a student, teacher, or institution has attained their short or long-term educational goals and is measured either by continuous assessment or cumulative grade point average (CGPA).

Yahaya (2020) viewed academic performance as determinants of students' performance in different courses over a period of time. This could be described, in other words, as the sum of an individual's performance in tests and examinations given within the institutions' system at the end of every semester or session. Academic performance is the product given by the students and it is usually expressed through school grades. It is a measure of the indicative and responsive abilities that express, in an estimated way, what a person has learned as a result of a process of education or training. Willcox (2019) define academic performance as the level of knowledge shown in an area or subject compared to the norm, and it is generally measured using the grade point average. The purpose of academic performance is to achieve an educational goal, learning. In this regard there are several components of the complex unit called performance. They are learning processes promoted by the school that involve the transformation of a given state, into a new state, and they are achieved with the integrity in a different unit with cognitive and structural elements. Performance varies according to circumstances, organic and environmental conditions that determine skills and experiences. Lamas (2017) figured out that several factors

involve academic performance, these are intellectual level, personality, motivation, skills, interests, study habits, self-esteem or the teacher-student relationship.

Laddunuri (2018) holds that academic performance really means three things; the ability to study and remember facts, being able to study effectively and see how facts fit together and form larger patterns of knowledge and being able to think for yourself in relation to facts and thirdly, to be able to communicate. According to Olivier et al., (2019) academic performance is defined as a student's ability to complete academic assignments, and it is assessed using objective criteria such as final course grades and grading point average. It is also a term that indicates a student's achievement after completing a course or subject from an institution. It measures students' learning across various academic subjects, which is assessed by formative and summative assessments. It refers to the outcome of students' efforts to attain some educational goals. Academic performance is the measurement of student achievement across various academic subjects.

Teachers and education officials typically measure achievement using classroom performance, graduation rates, and results from standardized tests. Academic performance definition by authors may be different but it refers to how well students do in their educational pursuits, primarily measured through grades, test scores, and overall comprehension of academic material. It is an essential aspect of a student's life for several reasons. Firstly, it provides a tangible measure of their understanding and mastery of subjects, giving both students and educators a clear sense of progress and areas needing improvement. Vyad (2024) pointed out that good academic performance often opens doors to higher education opportunities, scholarships, and competitive programs, playing a crucial role in shaping a student's future career and prospects. Beyond this, excelling academically can boost a student's confidence and motivation, encouraging a lifelong love of learning. It also develops critical thinking and problem-solving skills, which are invaluable in both professional and personal life.

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In essence, academic performance is not just about grades; it is about preparing students for success in an ever-changing world. The academic performance of students is a central concern in the field of education, with profound implications for their future success and societal well-being (Suleiman, Okunade, Dada & Ezeanya, 2024). Academic performance among students is a critical metric for assessing the effectiveness of educational systems worldwide.

Effective Teacher Training on STEM and How it Affects Students' Academic Performance

When looked at individual studies, a plethora of studies reported the impact of teacher factors on student achievement and motivation. More specifically, teachers' educational background (e.g., in- or out-of-field teaching) and other teacher attributes have significant associations with student outcomes in STEM (Wayne & Youngs, 2019). Certified teachers had a positive impact on student outcomes when compared to uncertified teachers (Lubienski, Lubienski & Crane, 2008). There is evidence for the strong associations of teachers' specialized content knowledge for teaching and their educational beliefs about teaching (which are part of teacher qualifications) to their instructional planning, decision-making, and practices (Hill, Umland, Litke, & Kapitula, 2012). Coupling this with the evidence that instructional practices naturally have direct impact on student outcomes, it is evident that teacher qualifications directly relate to student outcome.

Research consistently shows a positive correlation between teacher quality and student achievement in STEM subjects. When teachers are confident and competent in STEM, students benefit through:

1. Improved comprehension of STEM concepts
2. Higher engagement and motivation to learn
3. Better performance in standardized tests and practical assessments
4. Increased likelihood of pursuing STEM careers

For example, Darling-Hammond et al. (2017) found that students taught by well-trained teachers perform significantly better in science and mathematics compared to those taught by underprepared teachers. Similarly, a meta-analysis by Lynch et al. (2019) confirmed that teacher professional development in STEM subjects has a statistically significant and positive impact on students' academic outcomes.

Furthermore, effective training fosters equity in learning outcomes, as trained teachers are better prepared to support underrepresented and disadvantaged student populations, thereby closing achievement gaps in STEM education (Banilower et al., 2018).

In today's world, where science and technology are pivotal to our future, the need for skilled professionals in STEM (Science, Technology, Engineering, and Mathematics) fields has reached unprecedented levels. This heightened demand emphasizes the significance of effective STEM education, beginning in the classroom. The vital link between classroom learning and career success in STEM is primarily forged by the teachers who guide, inspire, and educate students. This highlights the essential role of STEM teacher training and its profound impact on students' journeys from the classroom to their careers (Sam, 2024).

Effective STEM education goes beyond merely delivering information; it involves engaging students, igniting their curiosity, and nurturing a passion for exploration and learning. This requires educators who are not only knowledgeable in their subjects but also adept in teaching methods that make STEM disciplines engaging and approachable. STEM teacher training programs are designed to arm educators with both the necessary content knowledge and effective teaching strategies. By emphasizing inquiry-based learning, problem-solving, and real-world applications, these programs prepare teachers to equip students for the challenges of STEM careers.

One of the most significant benefits of STEM teacher training is its ability to connect theoretical knowledge with practical application. Through thorough training, teachers learn how to



blend technology, engineering, and mathematical concepts with hands-on learning experiences. This method not only enhances students' comprehension and retention of complex topics but also provides them with insight into how these concepts are utilized in real-world scenarios. Consequently, students are better prepared to transition from academic settings to professional environments, where they can apply their knowledge to address real-world challenges. Furthermore, well-trained STEM educators play a crucial role in inspiring and nurturing the next generation of innovators and problem-solvers. By fostering an engaging and supportive classroom atmosphere, these teachers can help demystify STEM fields, making them more accessible and attractive to a broader array of students. This encouragement is vital for cultivating a diverse workforce capable of addressing future challenges.

The impact of STEM teacher training reaches far beyond the confines of the classroom. It is an essential factor in preparing students for successful careers in STEM disciplines, bridging the divide between academic learning and practical application, and inspiring a diverse and competent future workforce. As we continue to navigate a rapidly changing technological landscape, the importance of investing in high-quality STEM education and teacher training becomes increasingly evident. This investment is not just in our educators but also in the future of our global society.

CONCLUSION

The quality of teacher training in STEM plays a pivotal role in enhancing students' academic performance. Well-structured professional development programs enable teachers to adopt modern, effective instructional strategies that make STEM subjects more accessible and engaging. Consequently, students gain deeper understanding, improved performance, and increased interest in STEM fields. To foster long-term improvements in STEM education, investments must be directed toward continuous, practical, and research-informed teacher training programs.

RECOMMENDATIONS

Based on the findings, it is recommended that:

1. Ministries of education and school administrators should implement ongoing, mandatory professional development programs focused on modern STEM teaching methodologies, including inquiry-based and project-based learning.
2. Training should emphasize practical applications of STEM concepts to help teachers effectively bridge classroom learning with industry and everyday life, thereby increasing student relevance and interest.
3. Utilize online platforms, simulations, and virtual labs as part of teacher training to enhance digital competencies and ensure educators can incorporate emerging technologies in their STEM instruction.
4. Establish teacher learning communities where STEM educators can collaborate, share best practices, reflect on experiences, and co-develop instructional strategies for more effective teaching.
5. Teacher training programs should include modules on culturally responsive pedagogy and strategies to support underrepresented and disadvantaged students, aiming to close existing achievement gaps in STEM education.

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