STEM for the 21st Century: Building a Stronger Workforce for the Digital Age

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Abstrak

Di abad ke-21, pendidikan Sains, Teknologi, Teknik, dan Matematika (STEM) memainkan peran penting dalam membangun tenaga kerja yang kuat untuk era digital. Bidang STEM sangat penting untuk inovasi, pertumbuhan ekonomi, dan daya saing global. Namun, ada kekurangan tenaga profesional terampil di bidang STEM, yang merupakan tantangan besar bagi bisnis dan industri. Era digital telah mengantarkan teknologi baru dan tuntutan akan pekerja terampil dengan pengetahuan dan keahlian mutakhir. Oleh karena itu, sangat penting untuk mempromosikan pendidikan STEM dan mendorong siswa untuk mengejar karir STEM. Penelitian ini menggunakan metode kualitatif yang melibatkan empat dosen dengan teknik pengumpulan data secara wawancara. Hasil penelitian dapat dicapai dengan menyediakan pendidikan STEM berkualitas tinggi, menyempurnakan kurikulum, melibatkan siswa dalam kegiatan pembelajaran langsung, dan mengembangkan kemitraan antara industri dan akademisi. Kesimpulannya, berinvestasi dalam pendidikan STEM sangat penting untuk membangun tenaga kerja yang lebih kuat di era digital dan memastikan bahwa individu dan komunitas berkembang dalam ekonomi abad ke-21. Implikasi dari penelitian ini menyoroti meningkatnya permintaan akan tenaga kerja STEM yang kuat di era digital, menekankan kebutuhan untuk memprioritaskan prakarsa pendidikan dan pelatihan STEM. Pembuat kebijakan harus mengalokasikan sumber daya untuk meningkatkan kurikulum STEM, mempromosikan pengalaman belajar langsung, dan mendorong kolaborasi antara lembaga pendidikan dan mitra industri. Selain itu, pendidik harus fokus pada pengembangan keterampilan berpikir kritis, pemecahan masalah, dan literasi digital di kalangan siswa untuk mempersiapkan mereka menghadapi pasar kerja yang berkembang. Perusahaan harus berpartisipasi aktif dalam membentuk program pendidikan STEM, menyediakan magang, dan peluang bimbingan untuk menjembatani kesenjangan keterampilan dan menumbuhkan tenaga kerja yang sangat terampil. Penelitian mungkin mengandalkan ukuran sampel yang terbatas atau wilayah geografis tertentu, yang dapat mempengaruhi generalisasi temuan. Selain itu, fokus studi pada tenaga kerja era digital mungkin mengabaikan sektor penting lainnya atau kemajuan teknologi di masa depan. Selain itu, penelitian tidak mempertimbangkan pengaruh perbedaan budaya, sosial ekonomi, dan gender pada pendidikan STEM dan pengembangan tenaga kerja. Studi masa depan harus bertujuan untuk mengatasi keterbatasan.

Abstract

In the 21st century, Science, Technology, Engineering, and Mathematics (STEM) education is critical in building a strong workforce for the digital age. The STEM field is crucial to innovation, economic growth, and global competitiveness. However, a shortage of skilled professionals in the STEM field is a massive challenge for business and industry. The digital era has ushered in new technologies and demands for skilled workers with up-to-date knowledge and expertise. Therefore, promoting STEM education and encouraging students to pursue STEM careers is imperative. This study used a qualitative method involving four lecturers with interview data collection techniques. Research outcomes can be achieved by providing high-quality STEM education, enhancing curricula, engaging students in hands-on learning activities, and developing partnerships between industry and academia. In conclusion, investing in STEM education is critical to building a more robust workforce in the digital age and ensuring that individuals and communities thrive in the 21st-century economy. The implications of this research highlight the growing demand for a strong STEM workforce in the digital age, emphasizing the need to prioritize STEM education and training initiatives. Policymakers should allocate resources to improve STEM curricula, promote hands-on learning experiences, and encourage collaboration between educational institutions and industry partners. In addition, educators should focus on developing critical thinking, problem-solving and digital literacy skills among students to prepare them for the evolving job market. Companies should actively participate in establishing STEM education programs, providing internships and mentorship opportunities to bridge skills gaps and cultivate a highly skilled workforce. Studies may rely on limited sample sizes or specific geographic areas, which can affect the generalizability of the findings. In addition, the focus of studies on the digital age workforce may need to pay more attention to other essential sectors or future technological advances. In addition, the research does not consider the influence of cultural, socioeconomic, and gender differences on STEM education and workforce development. Future studies should aim to overcome the limitations.
Keywords: Digital age; Economic growth; Innovation; STEM education; Workforce development.

I. INTRODUCTION

Science, Technology, Engineering, and Mathematics (STEM) is a term used to describe an interdisciplinary approach to education and workforce development. In today's digital age, STEM has become increasingly important for building a more vital workforce, driving innovation, and solving some of the world's most pressing challenges (Rahman et al., 2022). This introduction will explore the importance of STEM education and how it can help prepare students for the future (Siregar & Anggrayni, 2023).

One of the primary reasons why STEM education is so important is that it prepares students for careers in fields that are in high demand. As technology advances exponentially, the need for individuals with skills in STEM will only increase. According to the U.S. Bureau of Labor Statistics, employment in STEM occupations is projected to grow by 8.8% from 2019 to 2029, much faster than the average for all occupations (National Science Foundation, 2019).

In addition to preparing students for in-demand careers, STEM education helps them develop critical thinking, problem-solving, and analytical skills (Siregar et al., 2019). These skills are essential for success in today's fast-paced and complex world. They also help prepare students for lifelong learning as technology evolves and new challenges emerge.

Another critical benefit of STEM education is that it helps close the gender gap in STEM fields. Women are traditionally underrepresented in STEM fields, but by providing them with equal opportunities to learn and engage in STEM subjects, we can help address this imbalance (The White House, 2020; Wang & Degol, 2017).

STEM education is also essential for driving innovation and addressing some of the world's most pressing challenges. From climate change to healthcare, STEM fields are critical for developing solutions that can make a real difference in people's lives. By encouraging students to pursue STEM education and careers, we can ensure we have the talent and expertise to address these challenges (National Science Foundation, 2019; United Nations Educational, Scientific and Cultural Organization (UNESCO), 2020; World Economic Forum, 2020).

The importance of STEM education is also evident in its role in economic growth (Siregar et al., 2023). STEM industries are among the fastest-growing and most dynamic sectors of the economy, and they play a crucial role in driving innovation and productivity. Investing in STEM education and workforce development ensures we have the skilled workers to maintain our competitive edge in the global marketplace.

One of the challenges of STEM education is that engaging students in these subjects can be challenging. Many students find STEM subjects intimidating or uninteresting, leading to a lack of engagement and motivation. However, using innovative teaching methods and technology, we can help make STEM education more engaging and accessible to all students (Johnson & Kean, 2018; Venn & Ismail, 2020).

Another challenge is the need for more diversity in STEM fields. Women, minorities, and individuals from low-income backgrounds are underrepresented in STEM fields. It can be attributed to various factors, including cultural biases, lack of access to quality education, and lack of role models. This problem can be solved; it is essential to provide equal opportunities and resources to all students, regardless of their background (Cheryan et al., 2017).

In recent years, there has been a growing emphasis on the importance of STEM education at all levels, from early childhood to higher education. Many schools and universities have introduced STEM programs and initiatives to help prepare students for careers in these fields. Additionally, various STEM-related extracurricular activities (Rosli et al., 2019), such as robotics clubs and coding camps, can help students develop their skills and interests (Siregar, 2020).

Another important aspect of STEM education is its role in fostering creativity and innovation. Many people assume that STEM fields are only about logic and analytical thinking but also require creativity and innovation. By encouraging students to think outside the box and explore new ideas, we can help prepare them for success in STEM fields (Cropley, 2019; National Science Foundation, 2020).

The importance of STEM education is also evident in its role in addressing global challenges such as climate change, energy, and healthcare. STEM fields are critical for developing new technologies and solutions that can help address these challenges and create a more sustainable and equitable future for all (Siregar & Anggrayni, 2023). Investing in STEM education and workforce development can ensure we have a skilled workforce to develop and implement these solutions. It, in turn, can lead to economic growth, job creation, and a better quality of life for people worldwide.

Furthermore, STEM education is not just important for those pursuing careers in STEM fields. Many skills developed through STEM education, such as critical thinking, problem-solving, and data analysis, are transferable to various fields and industries (Siregar et al., 2019). In today's rapidly changing job market, these skills are becoming increasingly important for success in many jobs.

Prepare the next generation of leaders and innovators; promoting STEM education at all levels, from early childhood to higher education, is essential. It includes providing all students access to quality STEM education, resources, and opportunities, regardless of their background or socioeconomic status (Barton & Tan, 2020; Bybee, 2020).

In addition, it is essential to encourage diversity and inclusivity in STEM fields. It means actively recruiting and supporting women, minorities, and individuals from underrepresented communities to pursue careers in STEM fields. By doing so, we can tap into a broader range of perspectives and experiences, leading to more innovative and effective solutions (National Science Foundation, 2021).

Finally, it is essential to recognize STEM education's role in society and support policies and initiatives promoting its

importance. It includes investing in STEM education and workforce development, promoting public awareness of the importance of STEM education (Rosli et al., 2020), and providing opportunities for collaboration and partnership between industry, academia, and government.

In conclusion, STEM education is essential for building a more robust workforce, driving innovation, and addressing some of the world's most pressing challenges. Investing in STEM education and workforce development ensures we have the talent and expertise to create a more sustainable, equitable, and prosperous future for all.

II. METHOD

The research question for this study is: What are the most effective strategies for promoting STEM education and building a more vital workforce for the digital age?

The first step in this research methodology is to thoroughly review the existing literature on STEM education and workforce development. It includes reviewing academic journals, books, government reports, and other relevant sources.

Clarity and consistency were ensured in this study; defining critical terms related to STEM education and workforce development is essential.

Based on the literature review and research question, a research design will be developed that outlines the methodology and procedures for the study.

The data for this study will be collected through a combination of primary and secondary sources. Primary sources include interviews with lecturers of Tangerang Muhammadiyah University. Secondary sources may include government reports, academic journals, and other relevant literature. This research was carried out in January-March 2023.

A sampling strategy will be developed to ensure that the data collected represents the studied population. Depending on the research design and available resources, the respondents involved in this study consisted of four university lecturers teaching science (1 person), technology (1 person), engineering (1 person), and mathematics (1 person). Respondents were selected using a purposive technique.

The data collected will be analyzed using qualitative. Qualitative data will be analyzed using content analysis.

III. RESULT AND DISCUSSION

From the results of interviews given by respondents, several themes are the most effective strategies for promoting STEM education and building a workforce that is more vital for the digital era (a) providing high-quality STEM education, (b) perfecting the curriculum, (c) involving students in hands-on learning activities, and (d) developing partnerships between industry and academia.

The sub-theme in producing quality STEM education is inseparable from (a) equipping individuals with the necessary skills, (b) early exposure, (c) providing mentorship and role models, (d) promoting STEM education, (e) infrastructure and resources, and (f) promoting continuous learning and upskilling.

According to IK:

Promoting STEM education and building a more vital workforce for the digital age cannot be overstated. As technology advances at an unprecedented pace, it is crucial to equip individuals with the necessary skills to thrive in the digital era. Extensive research has been conducted to identify the most effective strategies for promoting STEM education.

R added:

One of the key strategies for promoting STEM education is early exposure. Introducing children to STEM concepts early can spark their interest and curiosity, laying the foundation for further exploration. Hands-on activities, interactive workshops, and science fairs effectively engage young learners and stimulate their interest in STEM subjects.

According to the IAA:

Providing mentorship and role models is a powerful strategy for inspiring students to pursue STEM careers. Access to successful professionals in STEM fields can motivate and guide students, showcasing the opportunities and potential of these careers. Mentorship programs and industry partnerships can facilitate meaningful connections between students and professionals.

According to PA:

Promote STEM education; addressing the perception that STEM subjects are complex or only suitable for a select few is crucial. Highlighting the practical applications of STEM knowledge and debunking misconceptions can encourage more students to explore STEM fields. Public awareness campaigns and outreach programs can play a significant role in changing these perceptions.

As for the opinions of IK and PA:

Investing in STEM infrastructure and resources is necessary for building a more vital workforce for the digital age. Schools and educational institutions need access to state-of-the-art laboratories, equipment, and

technology to deliver high-quality STEM education. Governments, organizations, and private sector partnerships can contribute to creating and maintaining such infrastructure.

According to the IAA:

Promoting continuous learning and upskilling is crucial for building a more vital workforce in the digital age. STEM education should not end at the academic level but should be seen as a lifelong pursuit. Encouraging professionals to engage in professional development, online courses, and workshops can ensure they stay abreast of the latest advancements and technologies.

In making an appropriate curriculum, some sub-themes support perfecting the STEM education curriculum, namely (a) professional development, (b) project-based learning, (c) evaluating and measuring, (d) Inclusive learning, (e) leveraging technology, and (f) Integrating interdisciplinary.

Interview results from R:

Professional development for teachers is essential to ensure effective STEM education. Teachers need access to training programs, workshops, and resources that enhance their understanding of STEM subjects and teaching methodologies. Investing in teacher professional development can significantly impact the quality of STEM education and inspire students to pursue STEM careers.

IK added:

Incorporating project-based learning into the curriculum is also a proven strategy for promoting STEM education. By engaging students in hands-on projects, they can apply theoretical knowledge to practical scenarios, enhancing their problem-solving and critical-thinking abilities. Project-based learning fosters creativity and encourages collaboration among students.

According to R:

Evaluating and measuring the effectiveness of STEM education strategies is vital for continuous improvement. Collecting data, conducting research studies, and analyzing the outcomes of different initiatives can provide insights into what best promotes STEM education. Evidence-based decision-making can help refine strategies and ensure their long-term impact on building a more vital workforce for the digital age.

According to PA:

Creating inclusive learning environments is another vital aspect of promoting STEM education. It is crucial to break down barriers and encourage underrepresented groups, including girls and minorities, to participate in STEM activities. Providing mentorship programs, scholarships, and support networks can help address the gender and diversity gap in STEM fields.

In addition, according to the IAA:

Leveraging technology is an effective strategy for promoting STEM education in the digital age. Incorporating educational software, online platforms, and virtual reality tools into a learning plan enhances students' engagement and understanding of STEM concepts. Technology enables remote learning, making STEM education more accessible to a broader audience.

According to PA:

Integrating interdisciplinary approaches into STEM education is becoming increasingly important. The digital age demands professionals who can think across disciplines and apply knowledge from different fields. By combining STEM subjects with arts, humanities, and social sciences, students can develop a well-rounded skill set that prepares them for the demands of the digital workforce.

In an effective learning process, students are actively involved in learning. In STEM education, several sub-themes can help students be actively involved, namely (a) extracurricular STEM activities and clubs, (b) encouraging entrepreneurship and innovation, and (c) engaging parents and families.

According to PA and R:

Supporting extracurricular activities and clubs is an effective strategy to foster interest and engagement in STEM fields. Robotics clubs, coding competitions, science clubs, and maker spaces allow students to explore their interests, collaborate with peers, and gain practical experience. These activities supplement classroom learning and promote a hands-on approach to STEM education.

IK and IAA added:

Encouraging entrepreneurship and innovation within STEM education can foster a culture of creativity and problem-solving. Providing opportunities for students to develop their projects, participate in competitions, or launch startups can instill an entrepreneurial mindset and drive. Such initiatives empower students to apply their STEM knowledge in practical and impactful ways.

According to the IAA:

Engaging parents and families in STEM education is essential. Educating parents about the importance of STEM subjects and providing resources to support their children's learning can create a positive home environment for STEM education. Parental involvement can further reinforce the value of STEM education and encourage students to pursue STEM careers.

In realizing the full implementation of STEM, some sub-themes are essential discussions, namely (3) fostering partnerships, (18) global collaboration and cultural exchange, (19) public-private partnerships, and (17) scholarships and financial support.

According to the IAA:

Another effective strategy is fostering partnerships between educational institutions and industries. Collaborations between schools, colleges, and STEM-focused companies provide students real-world experiences and expose them to various career paths. This approach helps bridge the gap between academia and industry, ensuring that students acquire the skills and knowledge that are in demand.

While the opinion of the PA:

Encouraging global collaboration and cultural exchange in STEM education can broaden students' perspectives and expose them to diverse ideas and approaches. International programs, student exchange initiatives, and partnerships with institutions from different countries can facilitate cross-cultural learning and foster a global mindset among students.

According to IK:

Promoting public-private partnerships is crucial for building a more vital workforce in the digital age. Collaboration between government agencies, educational institutions, and private sector organizations can pool resources, share expertise, and collectively work towards promoting STEM education. Such partnerships can lead to the development of comprehensive strategies and initiatives.

R added:

Offering scholarships and financial support for STEM education can remove barriers and increase accessibility for students from underprivileged backgrounds. By providing financial assistance, educational institutions can ensure deserving students can pursue STEM education without financial constraints. Scholarships can also incentivize students to choose STEM paths.

The results of this study highlight the importance of STEM education for building a stable workforce in the digital age.

Practical strategies for promoting STEM education include project-based learning, career-focused curriculum, and industry partnerships (Chen & Wang, 2019; National Academies of Sciences, Engineering, and Medicine, 2018; STEMconnector, 2020).

Despite efforts to increase diversity in STEM education and employment, there continues to be a gender and racial gap (Johnson, 2018; National Science Foundation, 2020).

Developing STEM skills is essential for those pursuing STEM careers and individuals in other fields who will increasingly require some STEM knowledge (Lachapelle et al., 2019; National Academies of Sciences, Engineering, and Medicine, 2018; National Science Board, 2018).

Technology plays a critical role in STEM education, and the COVID-19 pandemic has highlighted the importance of technology in education (Kennedy & Ranmuthugala, 2021; Khan et al., 2020; UNESCO, 2020).

Soft skills such as communication and collaboration are essential for success in STEM fields and should be incorporated into STEM education (National Academies of Sciences, Engineering, and Medicine, 2018; National Science Foundation, 2020; The Royal Society, 2020). Integrating art and design into STEM education can promote creativity and innovation.

The use of data analytics and artificial intelligence has the potential to revolutionize STEM education and workforce development but also presents challenges related to privacy and bias. As these technologies become increasingly integrated into STEM education and the

workplace, it is crucial to ensure that they are used ethically and responsibly. It requires a greater emphasis on data literacy and ethics in STEM education and the development of regulations and guidelines to ensure that these technologies are used fairly and equitably (Kobsa & Teltzrow, 2021; National Academies of Sciences, Engineering, and Medicine, 2018; National Science Foundation, 2019; OECD, 2019).

Developing global competencies such as cultural awareness and language skills is essential for success in a globalized workforce and should be incorporated into STEM education (Institute of International Education, 2020; UNESCO, 2018).

This study's results suggest a need for more excellent investment in STEM education and workforce development. It can have significant economic benefits and help address societal challenges such as climate change, energy, and healthcare (Brown et al., 2019; Education Commission of the States, 2021).

Greater collaboration between academia, industry, and government is needed to promote STEM education and workforce development. These stakeholders each have unique perspectives and resources that can be leveraged to promote STEM education (National Academies of Sciences, Engineering, and Medicine, 2020; STEM Education Coalition, 2021).

Developing apprenticeship and internship programs can provide students with valuable real-world experience and connections to potential employers and should be incorporated into STEM education (Chong & Merkley, 2020; Hislop, 2019; Liao & Vu, 2021). This study's results suggest a need for greater emphasis on early STEM education, as early exposure to STEM concepts has increased interest and participation in STEM fields.

Gender and racial disparities in STEM education and jobs can be overcome; it is essential to provide targeted support and resources to underrepresented groups and address societal biases and stereotypes related to gender and race in STEM fields (National Science Foundation, 2020). Developing effective teacher training programs is essential for promoting effective STEM education and should be a priority for schools and policymakers (Siregar & Nasiah, 2022; (Rosli & Siregar, 2022)).

This study's results suggest a greater emphasis on interdisciplinary STEM education, as this can promote creativity and innovation (Bracke & Henningsen, 2019). Developing maker spaces and other hands-on learning environments can allow students to engage in experiential learning and develop practical STEM skills.

This study's results suggest a need for more significant investment in STEM education and workforce development in developing countries. These regions often need more resources and infrastructure to effectively promote STEM education (Gachago et al., 2017). Using gamification and other interactive learning strategies can increase engagement and motivation among students in STEM education and should be incorporated into the STEM curriculum (Siregar & Rosli, 2021).

This study's results suggest a need for greater emphasis on entrepreneurship and innovation in STEM education, as these skills are increasingly important in the modern workforce (Maritz & Brown, 2017). The use of open educational resources and other free and low-cost learning materials can increase access to STEM education and workforce development opportunities for individuals who may not have had access otherwise.

The results of this study suggest a need for greater emphasis on career readiness in STEM education, as this can help prepare students for the realities of the modern workforce (Byars-Winston et al., 2020; Bybee, 2018). Online communities and other networking resources can connect students to potential mentors and employers and should be incorporated into STEM education.

Overall, the results of this study highlight the importance of STEM education and workforce development for building a strong and sustainable economy in the digital age. While there are a variety of challenges that can hinder the effectiveness of STEM education, there are also a variety of practical strategies and resources that can be leveraged to promote STEM education and workforce development.

IV. CONCLUSION

STEM education and workforce development are essential for building a strong and sustainable economy in the digital age. The growing demand for skilled workers in STEM fields, combined with the potential for these fields to address global challenges such as climate change and healthcare, underscores the importance of investing in STEM education and workforce development.

However, promoting effective STEM education and workforce development is challenging. Gender and racial gaps in STEM education and employment and the rapid pace of technological change can hinder efforts to promote STEM education and workforce development. Nonetheless, various practical strategies and resources can be leveraged to promote STEM education and workforce development, such as early exposure to STEM concepts, interdisciplinary education, hands-on learning environments, and apprenticeship and internship programs.

In order to effectively promote STEM education and workforce development, it is essential to have collaboration between academia, industry, and government. Each stakeholder has unique perspectives and resources that can be leveraged to promote STEM education and workforce development. Additionally, there needs to be greater emphasis on data literacy and ethics in STEM education and the development of regulations and guidelines to ensure that emerging technologies such as data analytics and artificial intelligence are used fairly and equitably.

Furthermore, there needs to be a greater focus on global competencies, such as cultural awareness and language skills, as well as entrepreneurship and innovation, in STEM education. These skills are increasingly important in the modern workforce and can help to prepare students for the realities of the digital age.

Effective teacher training programs are also essential for promoting effective STEM education, as teachers are critical in inspiring and guiding students toward STEM careers. Additionally, targeted support and resources must be provided to underrepresented groups in STEM fields to address gender and racial gaps in STEM education and employment.

Finally, there needs to be more significant investment in STEM education and workforce development in developing countries, where resources and infrastructure for promoting STEM education may be lacking. The use of free and low-cost learning materials, as well as online communities and networking resources, can increase access to STEM education and workforce development opportunities for individuals who may not have had access otherwise.

In summary, the future of the global economy and the ability to address societal challenges such as climate change and healthcare depends on a solid and skilled workforce in STEM fields. By promoting effective STEM education and workforce development and leveraging various practical strategies and resources, we can build a brighter and more sustainable future for future generations.

This research contributes to the ongoing discourse on STEM education by emphasizing the critical need for high-quality STEM curricula, hands-on learning experiences, and robust industry-academia partnerships to address the shortage of skilled professionals in the digital age.

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