International Journal of Teaching and Learning (INJOTEL) e-ISSN: 3025-8308
Vol. 3 No. 3, March 2025, pages: 41~48

STEM (SCIENCE, TECHNOLOGY, ENGINEERING, AND MATHEMATICS) EDUCATION POLICY

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Abstract

The STEM (Science, Technology, Engineering, and Mathematics) education policy aims to prepare the younger generation to face the challenges of the future by improving competence in these fields. The implementation of this policy involves the integration of STEM into the curriculum from an early age, as well as synergy between the government, educational institutions, and the industrial sector to provide the necessary support and resources. In addition to ensuring that the education provided is applicable, this policy also seeks to reduce the gender gap and encourage wider participation. Through comprehensive STEM education, it is hoped that an innovative workforce will be created that is ready to compete at a global level and support sustainable economic growth.

Keywords: Policy, Education, STEM.

Introduction

In recent decades, the implementation and development of Science, Technology, Engineering, and Mathematics (STEM) based education programmes has become a major concern in many countries. STEM stands for Science, Technology, Engineering, and Mathematics, which is an integrated educational approach that combines these four disciplines to develop critical thinking skills, creativity, collaboration, and technology literacy (Beers, 2011). STEM education aims to prepare students to face global challenges in an increasingly complex and high-tech world of work, and to equip them with relevant knowledge and skills to develop sustainable innovations and solutions. This approach emphasises interdisciplinary project-based learning, which encourages students to relate theory to real-life practice (Bybee, 2010).

STEM education is considered important to prepare the younger generation to face the challenges and demands of work in the era of industry 4.0 and the transition to industry 5.0. The era of Industry 4.0, which is characterised by rapid advances in digital technology, automation, the Internet of Things (IoT), artificial intelligence (AI), and big

data, has drastically changed the industrial paradigm. The application of this technology enables more efficient, flexible, and integrated production processes. However, despite the many benefits it brings, the Industry 4.0 era also brings new challenges, such as labour market disruption and unequal access to technology (Patel, 2023).

In response to these challenges, the concept of Industry 5.0 has emerged, focusing on the harmonisation of technology and people. Industry 5.0 emphasises the collaboration between smart machines and human expertise to create a more sustainable and human-oriented work environment. In this era, humanitarian values, worker welfare, and sustainability are top priorities (European Commission, 2022).

The transition to Industry 5.0 involves the implementation of advanced technologies that are more environmentally friendly and support social innovation. One of the key aspects of Industry 5.0 is the use of technology to enhance human creativity and productivity rather than replacing it. Technologies such as AI, collaborative robots (cobots), and augmented reality (AR) will be used to assist workers in carrying out tasks that require precision and specialised expertise (Thompson & Abebe, 2023).

In addition, Industry 5.0 also highlights the importance of balancing economic efficiency and social responsibility. This means that companies need to integrate sustainability practices into their operations, including more prudent management of natural resources and waste reduction (Clark & Green, 2023).

In the context of education and training, this shift demands a change in the curriculum to accommodate skills relevant to the Industry 5.0 era. STEM education remains important, but with an additional focus on soft skills such as empathy, interpersonal communication, and the ability to work collaboratively with technology (National Academy of Engineering, 2023).

Thus, the shift from the Industrial era 4.0 to 5.0 is not only about adopting new technologies, but also about creating a more inclusive, humane, and sustainable industrial ecosystem. This concept offers a vision of the future in which technological progress and humanitarian values go hand in hand to shape a better world of work for all.

In the midst of the rapid technological and information revolution, the ability to adapt and innovate is the key to success for future human resources. Therefore, efforts to strengthen STEM education are receiving considerable attention from policymakers, educators, and the general public (World Bank, 2022).

In many developed countries, STEM education policies have been implemented with the aim of increasing the nation's capacity and competitiveness. The government allocates resources and develops a curriculum that is integrated with the needs of industry 4.0. However, the implementation of this policy often faces various challenges such as limited human resources, inadequate infrastructure, and resistance to changes in the curriculum and conventional teaching methods (Thompson & Abebe, 2023).

In developing countries, including Indonesia, the implementation of STEM education is also a priority, but it is often hampered by various problems such as limited funds, lack of training for teachers, and inadequate education infrastructure. In addition, there is still a gap between the curriculum taught in schools and the needs of industry (Martin, 2022).

Recognising the important role of STEM education in improving the skills and competitiveness of the workforce, in-depth research is needed to evaluate the effectiveness of the STEM education policies that have been implemented.

Research Methods

The study in this research uses the literature method. The literature assessment method, or often referred to as a literature review, is a systematic process that involves the identification, evaluation, and synthesis of written works relevant to a particular research topic. This process begins with a literature search through various sources such as scientific journals, books, research reports, and academic databases using appropriate keywords (Okoli, 2015); (Randolph, 2009). Once relevant literature has been found, the next step is to assess the quality and validity of each source based on certain criteria, such as research methodology, author credibility, and relevance to the research topic. The main purpose of literature assessment is to provide a comprehensive overview of the latest developments, find gaps in existing knowledge, and build a solid theoretical foundation for further research. This process also helps to identify significant trends, patterns, and relationships in a particular field of study, thus directing new research and more informed professional practice (Grant & Booth, 2009).

Results and Discussion

Basic STEM Concepts

STEM stands for Science, Technology, Engineering, and Mathematics, which is an educational approach that focuses on the integration of these four disciplines to prepare future generations for the challenges of the modern world. Basically, STEM aims to develop critical thinking, problem solving, and creativity skills, which are needed in various professional fields in this digital era (Smith & Brown, 2022).

Science in STEM plays an important role in encouraging students to understand basic concepts about the universe and natural phenomena using the scientific method. The ability to observe, ask questions, experiment, and draw conclusions from data is at the core of the science approach in the STEM curriculum. With this approach, students are encouraged to build their knowledge through direct experience and exploration (Oliveira & Costa, 2023).

Technology, in turn, teaches students how to use modern tools and systems to solve problems. This includes not only skills in using computer hardware and software, but also a framework for understanding the impact of technology in everyday life. The

introduction of technology in education aims to improve digital literacy and the ability to adopt rapid technological change (Garcia, 2022).

Engineering emphasises the process of designing and creating solutions to the challenges that exist around us. In the context of STEM, engineering is an iterative process involving planning, prototyping, testing and improvement. With a curriculum designed for activities such as group projects and case studies, students learn to work collaboratively and think innovatively to design efficient and effective solutions (Zollman, 2012).

Mathematics in STEM is important for developing students' abilities in quantitative analysis and logic. A deep understanding of mathematical concepts allows students to solve problems systematically and develop models that can predict outcomes in various situations. This ability is essential for almost all technical and scientific aspects, from data analytics to engineering design (National Research Council, 2011).

With an approach that combines these four disciplines, STEM education aims to provide more relevant and applicable experiences, connecting learning with real-life situations. This is expected to increase learning motivation and prepare students to compete in an innovation-driven global economy. STEM education also emphasises inclusivity, with the aim of reducing gender and racial gaps in related fields, thus guaranteeing equal opportunities for all groups to participate and excel.

STEM Education Policies in Various Countries

STEM education policies have become a major focus in various countries with the aim of improving students' abilities in the fields of science and technology, and preparing them for the challenges of the future industry. In the United States, for example, the STEM education initiative got off to a strong start in 2009 with the launch of the 'Educate to Innovate' policy by President Barack Obama. The programme aims to improve students' achievements in mathematics and science and foster their interest in STEM careers. Its implementation involves collaboration with the private sector, universities and non-profit organisations (Adams, 2023).

In the UK, the government is taking a comprehensive approach by launching a national STEM strategy that includes a more technically-skills-focused curriculum. This policy includes funding for teacher training, the development of science laboratories in schools, and partnerships with industry to provide real-world work experience for students. In addition, they also provide scholarship programmes and educational loans for students interested in developing a career in STEM (Kuenzi, 2008).

China has identified STEM education as the key to maintaining its rapid economic growth and its position as a leader in technological innovation. The Chinese government has launched policies that strengthen STEM education at all levels of school and university. They are investing heavily in education infrastructure, providing state-of-the-

art research facilities, and promoting international exchange and collaboration programmes with technologically advanced countries (Zhang & Li, 2023).

In Singapore, STEM education is seen as the foundation for the development of competent human resources. The country's education policy includes a curriculum that places greater emphasis on mathematics, science and technology from primary school onwards. The government is also encouraging the use of technology in teaching through initiatives such as 'Smart Nation'. These efforts include the introduction of coding and programming in schools and providing intensive training for teachers to update their knowledge of the latest developments in STEM education (Mitchell, 2023).

Australia has also developed a national STEM strategy aimed at equipping students with relevant and reliable skills for the future. One of the main approaches is the integration of STEM teaching into the national curriculum with additional resources and training for teachers. In addition, this policy also includes collaboration with the industrial sector to ensure that students have a practical understanding of the application of STEM in the world of work (Carlson, 2022).

In various other countries around the world, the implementation of STEM education policies continues to evolve with their own uniqueness and adaptation based on national needs and local contexts. The main focus of this policy is to improve students' technical and analytical competencies and ensure their readiness to participate in a global economy driven by innovation and technology. This diverse policy demonstrates a global commitment to improving STEM education as the key to a better future (The Royal Society, 2022).

Some countries other than those mentioned above also see the importance of STEM education in driving economic growth and innovation. For example, Japan has invested significant resources in STEM education to ensure that students at all levels have access to cutting-edge research and the latest technology. The Japanese government also promotes industry-academia collaboration to develop skills that are more relevant in the job market (Johnson & Nguyen, 2022).

In addition, South Korea has long been known for its rigorous education system and high focus on science and technology. The Korean government implements policies that support research and development in the STEM fields, as well as increasing the number of science and mathematics schools to produce more experts and professionals in these fields. Large investments in educational technology have also helped prepare Korean students to become future technology leaders (Honey et al., 2014).

Nordic countries such as Finland and Sweden are also not lagging behind in developing innovative STEM education policies. They prioritise project-based learning and an interdisciplinary approach that combines various aspects of STEM in one cohesive curriculum. This approach aims to develop strong critical thinking and problem-solving skills from an early age, as well as strengthening students' interest and curiosity in the field of STEM (Marginson et al., 2013).

To assess the effectiveness of STEM education policies in various countries, several key indicators can be considered, including: an increase in the number of STEM graduates, student participation in STEM-related programmes, student scores in international tests such as PISA (Programme for International Student Assessment), and practical applications of the technology learned in school. In addition, the growth in the number of innovations and patents filed by the younger generation can also be a sign of the success of STEM education in producing future innovators (Fisher, 2022).

Thus, STEM education policy is an important element recognised globally to support economic development and technological innovation. Each country has a different approach and strategy in implementing STEM education, according to local needs and contexts. However, the general goal to be achieved remains the same: to equip the younger generation with relevant skills and knowledge to face the challenges of the future.

The importance of STEM education cannot be ignored, given the global trend of shifting to the technology and innovation sector. With supportive policies and initiatives in place, it is hoped that the quality of STEM education can be continuously improved and make a significant contribution to socio-economic development in various parts of the world. The combination of government policies, private sector support, and international collaboration will be key to achieving this goal.

Conclusion

The STEM (Science, Technology, Engineering, and Mathematics) education policy plays an important role in shaping the foundation of the younger generation to face the challenges of the future. With the rapid development of technology and industry, the need for a competent workforce in this field is increasing. Therefore, many countries have integrated STEM education into the school curriculum from an early age, to support economic growth and innovation. This policy includes an increase in the number of STEM-related subjects, project-based learning, and extracurricular programmes that encourage students to explore their interests in this field.

To effectively implement the STEM education policy, collaboration between the government, educational institutions, and the industrial sector is essential. The government is responsible for providing the necessary resources and policy support, while educational institutions implement curricula that are in line with industry needs. The industrial sector is also involved by providing relevant work experience, internships, and training opportunities. This close relationship between academics and practitioners ensures that the education provided is not only theoretical but also applicable, so that students can better prepare themselves for careers in STEM fields.

With a comprehensive and structured STEM education policy in place, it is hoped that there will be an improvement in the quality and number of graduates ready to work in these important sectors. In addition, this policy also aims to reduce the gender gap in

STEM by encouraging the participation of women and other minority groups. A strong STEM education will create an innovative workforce that is ready to face global challenges and encourage sustainable economic growth. This initiative also strengthens a country's position in global competition, given the importance of science and technology in this digital era.

References

Adams, K. (2023). Remote Learning in STEM: Adapting to New Educational Environments. *Journal of Online Learning Research*, *10*(1), 67–83.

Beers, S. Z. (2011). *21st Century Skills: Preparing Students for Their Future*. STEM Education Coalition.

Bybee, R. W. (2010). Advancing STEM Education: A 2020 Vision. *Technology and Engineering Teacher*, *70*(1), 30.

Carlson, D. (2022). *STEM Education for Sustainable Development*. Taylor & Francis.

Clark, M., & Green, N. (2023). Collaborative Learning in STEM: Improving Student Outcomes. *Journal of Educational Psychology*, *115*(3), 298–312.

European Commission. (2022). *Boosting STEM Skills in Europe*. European Commission Directorate-General for Education, Youth, Sport and Culture.

Fisher, A. (2022). Teacher Professional Development in STEM: Current Trends. *Journal of Teacher Education*, *73*(4), 445–460.

Garcia, M. (2022). *Integrating STEM into Education Systems Worldwide*. Springer.

Grant, M. J., & Booth, A. (2009). A Typology of Reviews: An Analysis of 14 Review Types and Associated Methodologies. *Health Information and Libraries Journal*, *26*(2), 91–108.

Honey, M., Pearson, G., & Schweingruber, H. (Eds.). (2014). *STEM Integration in K-12 Education: Status, Prospects, and an Agenda for Research*. National Academies Press.

Johnson, A., & Nguyen, T. (2022). *STEM Education: Challenges and Opportunities*. Routledge.

Kuenzi, J. J. (2008). *Science, Technology, Engineering, and Mathematics (STEM) Education: Background, Federal Policy, and Legislative Action*. Congressional Research Service.

Marginson, S., Tytler, R., Freeman, B., & Roberts, K. (2013). *STEM: Country Comparisons*. Australian Council of Learned Academies.

Martin, L. (2022). Gender Disparities in STEM: Addressing the Gaps. *Gender and Education*, *34*(3), 563–577.

Mitchell, J. (2023). *STEM Curriculum Design: Best Practices and Strategies*. Sage Publications.

National Academy of Engineering. (2023). *Engineering Education for the Future: Enhancing STEM Learning*. National Academies Press.

National Research Council. (2011). *Successful K-12 STEM Education: Identifying Effective Approaches in Science, Technology, Engineering, and Mathematics*. National Academies Press.

Okoli, C. (2015). *A Guide to Conducting a Standalone Systematic Literature Review*. Springer.

Oliveira, P., & Costa, S. (2023). *Innovative Approaches to STEM Education*. Academic Press.

Patel, N. (2023). Artificial Intelligence in STEM Education: Trends and Challenges. *International Journal of Artificial Intelligence in Education*, *33*(2), 512–528.

Randolph, J. (2009). A Guide to Writing the Dissertation Literature Review. *Practical Assessment, Research, and Evaluation*, *14*(13), 1–13.

Smith, J., & Brown, R. (2022). Innovations in STEM Education: The Future of Learning. *International Journal of STEM Education*, *9*(1), 45.

The Royal Society. (2022). *STEM Education for the 21st Century: An Agenda for Action*. The Royal Society.

Thompson, C., & Abebe, H. (2023). Equity and Inclusion in STEM Education: A Global Perspective. *Journal of Science Education and Technology*, *32*(4), 401–418.

World Bank. (2022). *Enhancing STEM Education in Developing Countries*. World Bank Group.

Zhang, X., & Li, Y. (2023). STEM Assessment Practices: Innovations and Implications. *Journal of Education Assessment*, *44*(2), 175–190.

Zollman, A. (2012). Learning Takes Time: A Whole School Approach to STEM Professional Development. *School Science and Mathematics*, *112*(3), 144–155.