Stem Education: Its Effects on the Quality of Teachers and Students in the 21st Century

Haerul Salam(✉)

Department of Primary Education, Graduate School Universitas Negeri Malang, Malang, Indonesia
haerul.salam.2221039@students.um.ac.id

Abstract. STEM education provides a particular context required for student learning in the 21st century. One of the st-century skills is digital literacy. Students' digital literacy skills need to be developed to ensure that students will be able to maximize the use of technology in 21st-century learning. This study aims to improve students' ability to think creatively using the STEM method in the learning process. This study was completed using the qualitative method. The results show that 1) the adoption of the STEM method in the learning process can improve the quality of 21st-century teachers and students because the STEM method is an interdisciplinary approach enabling students to use science, technology, engineering, and mathematics in real-life contexts connected to their schools, the world of work and the global world; 2) the obstacles include the lack of teacher preparation in teaching and understanding the diversity of student behavior; 3) to enhance the effectiveness of learning activities, teachers must be more creative, innovative and present good competencies. To improve their competence, teachers can continue to learn and attend training.

Keywords: STEM Education · Quality of Teachers and Students abd 21 · learning process · reative thinking

1 Introduction

As we currently live in the early 21st century, when the social and economic world has changed, communities are becoming more socially diverse, inducing the emergence of 21st-century skills. The 21st-century skillsr are a new set of skills needed to prepare students to survive and work in the digital age. North Central Regional Education Laboratory and Metiri Group have introduced a 21st-century education model known as enGauge 21st Century Skills. According to this model, four main criteria are significant for generating generations with excellent survival skills in the 21st century. Chapoo (2019) described that those four criteria included digital literacy, inventive thinking, effective communication, and high productivity.

The first 21st-century skill is digital literacy which includes communication competence, data analysis and interpretation, model understanding and assessment, task management and task prioritization, involvement in problem-solving, along with protecting

A. P. Wibawa et al. (Eds.): ICE 2022, ASSEHR 736, pp. 31–39, 2023.
https://doi.org/10.2991/978-2-38476-020-6_4

well-being and security (Chapoo 2019). Students' digital literacy should be enhanced to ensure their ability to use technology in 21st-century learning.

The second skill is inventive thinking. Inventive thinking is defined as a cognitive activity that supports the application of creative and critical thinking, along with problem-solving skills, through innovative or specially designed activities. NCREL and Metiri Group (Chapoo 2019) and the Committee on Workforce Needs in Information Technology (2001) have described several elements of inventiveness, consisting of adapting to and managing complexity, self-regulation, curiosity, willpower to take risks, and promoting higher levels of thinking.

The third skill is effective communication. In this 21st century, every individual should have effective communication skills, which include information delivery, teamwork, interpersonal skills, social responsibility, interactive communication, and environmental communication (Chapoo 2019).

The fourth skill is high productivity. According to NCREL and Metiri Group (Chapoo 2019), high productivity is defined as students' ability to proficiently produce relevant, high-quality, intellectual, current, and original information products. In addition, high-productivity skilled students are also competent in delegating and arranging assignments based on importance and priority. They also present astonishing skills in planning and producing high-quality products.

Our observation conducted in April–June 2022 suggested low students' creative thinking abilities due to the learning model that was not in accordance with the material. Accordingly, one of the alternative learning models that can be used by teachers is the STEM method. STEM approach aids students in connecting their learning to their environment, the real world, and everyday life, resulting in students' better understanding without being involved in investigative activities (Winarni et al., 2016).

Low conceptual mastery affects students' creative thinking skills because they require a more comprehensive conceptual knowledge to comprehend a material presented in a more understandable manner, provide interpretation and apply it (Hermansah et al. 2017). One available solution to overcome this issue is the application of the STEM model. Greater creative thinking skills bears positive effects on students' life. One of the constructive impacts offered by creative thinking skills is enhanced self-actualization and potential. Besides, since their actions are carried out quickly, they can provide accurate outcomes, and they produce numerous, original, and distinctive works, fascinating their surrounding environment. Creative thinking is also needed to solve the problems in the community (Mardhiyana et al., 2016).

However, Indonesian students present relatively low creative thinking skills, especially in the field of science. The data from the 2018 PISA results showed that Indonesian results are Lower than in 2015. Besides, the 2018 PISA results showed that Indonesia ranked 9th from the bottom (71), with an average score of 396. It is above Saudi Arabia, which had an average score of 386, while China occupied first place with an average score of 590.

Several studies have been conducted to improve students' low creative thinking. Previous research conducted by Jayadinata et al. (2016) indicates that learning with discovery learning models and conventional models can improve students' creative thinking

skills, with the discovery learning model presenting better improvement in students' creative thinking skills. Meanwhile, a study conducted by Rahayu (2011) reported increasing learning outcomes and creative thinking abilities of seventh-grade students of state junior high school students after they attended learning with the process skills approach in the heat material. In addition, research conducted by Wardani et al. (2019) indicated an increase in students' creative thinking skills after they attended learning using the mind mapping model.

However, there has been no study that investigates the efficiency of the STEM model in improving students' creative thinking skills, even though the STEM method relates the material to student's real life. Besides, the solutions offered previously are not contextual, so this study examines the use of the STEM method.

An integrated approach is highly expected in the education field. Additionally, STEM can help the students to solve real-world problems by applying multi-disciplinary concepts (Shernoff et al. 2017), such as critical thinking, collaboration, and creativity (Burrows and Slater 2015). However, most teachers have received training focusing on only one discipline (Honey et al. 2014). Also, most schools and classes still segregate STEM courses into different departments and learning subjects at all levels of education. Therein lies a significant challenge for educators and administrators in promoting integrated STEM courses.

Science, Technology, Engineering, and Mathematics (STEM) are closely related content areas. One way to understand their complex interrelationships is by using real-world context. Engineering is a discipline that applies scientific knowledge and mathematical computations to design processes, products, or technology to solve problems (Chai 2018). Technology can facilitate the advancement of scientific and mathematical knowledge and engineering design. The primary core competencies required in the recent society are sufficient STEM knowledge and the ability to integrate these knowledge resources to design solutions to problems.

STEM education aims to improve STEM literacy which includes knowledge and understanding of scientific and mathematical concepts, along with required processes in personal decision-making, participation in civic and cultural affairs, and economic productivity. STEM education also aims to persuade students to explore further education and careers in STEM-related fields. A literature review showed that children undergo numerous developmental between 6 and 12 years old, especially in cognitive development (Canadian Federation of Child Care in (Khanlari, n.d.). Therefore, STEM education is more effective if implemented as early as possible. Therefore, the foundations of science, technology, and mathematics education should be provided in elementary school (Marulcu 2010). Early introduction to STEM education facilitates students' understanding of the materials (Marulcu 2010), reducing barriers to getting into demanding jobs related to STEM.

Funding for innovation and entrepreneurship have now prioritized STEM-related field on a national level, such as the 21st Century Minds (21CM) Accelerator Program. This program aims to prepare children with the 21st-century skills required for their digital careers, including the ability to think intelligently and creatively, solve problems, persevere and take risks, have strong digital skills, and the ability to work collaboratively (Chapoo 2019).

Education in science, mathematics, engineering, and technology (STEM) is widely recognized as an urgent national priority (Honey et al. 2014). Excellence in STEM skills is the central determining factor for employment, productivity, and competitiveness in a variety of sectors and areas, including health, technology innovation, manufacturing, information distribution, politics, and culture (Asunda 2014; Peters 2006). Innovation in the STEM field increasingly drives economic growth and improves human quality of life. Thus, integrated STEM education has been a meta-discipline, focusing on innovation, designing solutions, and leveraging technology (Kelley and Knowles 2016). Consequently, students are expected to engage in a rigorous curriculum, with instruction and assessment in mathematics, science, and engineering design (Kelley and Knowles 2016).

Our observation carried out in April–June 2022 at the Imppres Kala Elementary School, Bima Regency, Indonesia, suggested that in the learning process, most of the teachers only focus on one subject per day, as opposed to obligatory thematic learning. Further, we observed some teachers only gave assignments in the form of drawing activities or even memorizing multiplications and then left the class. As a facilitator, the teacher should accompany the students as they carry an essential role in students' learning. Besides, teachers should also help and encourage students to develop some skills while also being a source of information, advice, and knowledge (Rahmawati, 2019). There are nine main roles of teachers in teaching and learning activities, namely informer, organizer, motivator, director, misiator, transmitter, facilitator, mediator, and evaluator, Sardiman in Rahmawati (2019). The current Indonesia 2013 curriculum emphasizes active student learning, where students learn from their experience and critical thinking while the teachers act as a facilitator.

The learning process in the 21st century has focused on globalization, the information society, the expansion of the technology industry, competition in the economy field, and increasing demand for a more creative workforce. To compete in this world of tomorrow, the Indonesian workforce must have 21st-century skills, which can be developed through the implementation of STEM education. The available literature suggests several STEM curriculum designs that require a combination of theory and practice in real situations, design processes, problem-solving abilities, and other related aspects to find possible solutions. STEM learning can be applied through the context of Problem-based learning (PBL), Science, Technology, and Society (STS), and Socio Scientific (SSI) education.

2 Method

This study was carried out at State Elementary School Inpres Kala, Bima Regency, West Nusa Tenggara, Indonesia. This study seeks to describe the STEM method for the learning process of 21st-century teachers and students to improve students' creative thinking skills. The data were obtained from interviews, documentation, and observations. The primary data sources in this research were the teachers and students, then followed by observations and documentation.

3 Results and Discussion

3.1 STEM Method for 21st-Century Teachers and Students' Learning Process to Improve Students' Creative Thinking Skills

Each course of STEM learning consists of observing, reading, experimenting, discussing, and closing activities. Each of that activities also applied the STEM aspects, namely observation, new idea formation, innovation, creativity, and society.

1. Observation, students make observations of their surrounding environment related to the science concepts being discussed in the learning process. This phase aims to help students understand the reason an event or problem occurs. For instance, in the learning of energy sources, students are asked to find as much information as possible about the use of energy sources, especially in their surrounding environment. In this stage, the teacher ensures that students observe the events that occur in everyday life and relate them to scientific concepts. Observations can be made through direct observation (using the five senses and interviews with local residents) or other relevant sources such as the internet, websites, articles, books, and so forth. Further, the students are asked to formulate and describe all the information and correlate them with the material being discussed in their learning.
2. New idea, the students are asked to look for or think of a new idea based on their obtained information. For instance, after students collect information about the use of energy sources, students are asked to think of an idea that provides innovations on the better use of existing energy sources. This stage requires analysis and critical thinking skills. The teachers have to provide motivation and ensure that students use all of their imagination to find new ideas. Besides, teachers should also direct students whenever they make mistakes.
3. Inovation, students are asked to consider what has to be done to generate new ideas. To help students get through this phase, they are asked to work together, discuss and present the results of the discussion. In this stage, all students in each group should actively participate and provide opinions and suggestions. Meanwhile, the teacher has to direct students in group discussions, primarily in assessing the most appropriate ideas to be proposed and completed.
4. Creativity, implementation of all opinions, and suggestions from the discussions. In this stage, students can translate their garnered ideas into sketches, drawings, or miniatures. The teacher's role in this stage is as a facilitator in encouraging students to use their overall imagination and decipher their ideas into draft drawings, sketches, or miniatures. So the teacher must ensure that all student ideas are included in their work.
5. Society, this stage aims to facilitate students present their value of new ideas for the real life of society.

Our interview results with the teachers indicated that STEM can improve the quality of teachers and students in the 21st century because this method is an interdisciplinary learning approach, allowing students to use science, technology, engineering, and mathematics in a real situation, such as their life in school, in their professional working

world, a and the global world. This learning is expected to motivate students to acquire their own knowledge. In accordance with the demands of the 2013 curriculum, teachers can also use one of the learning models, such as the STEM model. This STEM learning model can help the students to solve real-world problems by applying concepts that cross various disciplines and their critical thinking, collaboration, and creativity (Estapa et al. 2017). Additionally, STEM can develop young students' understanding of the multiple roles of engineering in society and help improve achievement, motivation, and problem-solving by contextualizing math and science content.

3.2 Obstacles Faced by Teachers in Using the STEM Method in the Learning Process

The STEM method has been confirmed capable of enhancing 21st-century teachers' and students' quality in the learning process, primarily students' creative thinking skills. In addition to the benefits being offered, the adoption of the STEM method also carries a number of obstacles, such as the lack of teacher preparation in teaching and understanding the diversity of student behavior, along with teachers' minimum ability to operate technology.

The Law of the Republic of Indonesia, number 14, the year 2005, concerning Teachers and Lecturers, defines a teacher as a professional educator whose main task is to educate, guide, teach, assess, train, and evaluate students starting from early childhood education, basic education, secondary education, and formal education. Thus, the teacher is a learning agent who acts as a facilitator, motivator, motivator, inspiration, and engineer of learning for students.

In addition, the Law of the Republic of Indonesia number 14 of the year 2005, article 8 also describes that teacher competencies include personality competencies, pedagogic competencies, social competencies, and professional competencies obtained through professional education.

3.3 Solutions to Overcome Obstacles in Using the STEM Method in the Learning Process

To increase the effectiveness of learning activities, teachers must be more creative and innovative while also enhancing their competencies. Have good competence. As mandated in the Law of the Republic of Indonesia number 14 of the year 2005, article 8, teacher competencies include personality, pedagogic, social, and professional competencies.

4 Conclusion

In the end, we conclude that the STEM method can enhance students' creative thinking skills, along with the quality of 21st-century teachers and students in the learning process. The STEM stages consist of 1) observation, 2) generating new ideas, 3) innovation, 4) creativity, and 5)society. The use of the STEM method in the learning process aids students' in attaining direct experience related to the learning material because the STEM

method is an interdisciplinary learning approach that enables students to use science, technology, engineering, and real math.

Acknowledgements. We would like to thank the teachers and students of State Elementary School Inpres Kala who were willing to support this study. We also would like to express our gratitude to Prof. Dr. Anang Santoso, M.Pd, and Dr. Ade Eka Anggraini, M.Pd for their guidance throughout this study, as well as doctoral students of the Elementary Education program of Universitas Negeri Malang.

References

Abdul, H.A., H.S.R.H. Raja, N.S.A.R. Sharifah, H.H. Mohd, H.A.K. Umar, and J. Juhazren. 2017. "Technology, Engineering and Mathematics (STEM) Education from the Cognitive, Affective and Behavioural Aspects." *IEEE International Conference on Teaching, Assessment, and Learning for Engineering (TALE)*, no. December: 6–12.

Bybee, Rodger W. 2013. *The Case for STEM Education_ Challenges and Opportunities-National Science Teachers Association.*

Cavenett. (2013). Pembelajaran STEM. *Journal of Chemical Information and Modeling*, *53*(9), 1689–1699.

Chai, Ching Sing. 2019. "Teacher Professional Development for Science, Technology, Engineering and Mathematics (STEM) Education: A Review from the Perspectives of Technological Pedagogical Content (TPACK)." *Asia-Pacific Education Researcher* 28 (1): 5–13. https://doi.org/10.1007/s40299-018-0400-7.

Chapoo, Suriya. 2019. "Enhancement of 9th Grader Students' 21st Century Skills through Inquiry-Based Questions in Integrated STEM Activity." *AIP Conference Proceedings* 2081 (March). https://doi.org/10.1063/1.5094015.

Fore, Grant A., Charles R. Feldhaus, Brandon H. Sorge, Mangilal Agarwal, and Kody Varahramyan. 2015. "Learning at the Nano-Level: Accounting for Complexity in the Internalization of Secondary STEM Teacher Professional Development." *Teaching and Teacher Education* 51: 101–12. https://doi.org/10.1016/j.tate.2015.06.008.

Green, Satasha L. 2014. *STEM Education: How to Train 21st Century Teachers. STEM Education: How to Train 21st Century Teachers.*

Harlow, Danielle B, Alexandria K Hansen, Jasmine K Mcbeath, and Anne E Leak. n.d. "Teacher Education for Maker Education : Helping Teachers Develop Appropriate PCK for Engaging Children in Educative Making," 265–80. https://doi.org/10.1007/978-3-319-97475-0.

Ibrahim, Ahmed, Mark W. Aulls, and Bruce M. Shore. 2017. "Teachers' Roles, Students' Personalities, Inquiry Learning Outcomes, and Practices of Science and Engineering:The Development and Validation of the McGill Attainment Value for Inquiry Engagement Survey in STEM Disciplines." *International Journal of Science and Mathematics Education* 15 (7): 1195–1215. https://doi.org/10.1007/s10763-016-9733-y.

John R Mcconnell. 2017. "A Model for Understanding Teachers ' Intentions to Remain in STEM Education." https://doi.org/10.1186/s40594-017-0061-8.

Khanlari, Ahmad. n.d. "The Use of Robotics for STEM Education in Primary Schools : Teachers ' Perceptions," 267–78. https://doi.org/10.1007/978-3-030-19913-5.

Kennedy, Ian G., Gloria Latham, and Hélia Jacinto. 2016. *Education Skills for 21st Century Teachers.* https://doi.org/10.1007/978-3-319-22608-8.

Nasrudin, D., C. Rochman, H. Y. Suhendi, I. Helsy, A. Rasyid, I. Aripin, W. Utami, and A. Mayasri. 2020. "STEM Education for Pre-Service Teacher: Why and How?" *Journal of Physics: Conference Series* 1563 (1). https://doi.org/10.1088/1742-6596/1563/1/012039.

Nadelson, Louis S, Janet Callahan, Patricia Pyke, Anne Hay, and Matthew Dance. n.d. "The Journal of Educational Research," no. October 2014: 37–41. https://doi.org/10.1080/00220671.2012.667014.

Prawvichien, Sutthaporn, Kulpatsorn Siripun, and Chokchai Yuenyong. 2018. "Developing Teaching Process for Enhancing Students' Mathematical Problem Solving in the 21st Century through STEM Education." *AIP Conference Proceedings* 1923. https://doi.org/10.1063/1.5019560.

Plessis, Anna E. du. 2018. "The Lived Experience of Out-of-Field STEM Teachers: A Quandary for Strategising Quality Teaching in STEM?"*Research in Science Education*, no. 1990: 1–35. https://doi.org/10.1007/s11165-018-9740-9.

Rahmawati, Mega, and Edi Suryadi. 2019. "Guru Sebagai Fasilitator Dan Efektivitas Belajar Siswa." *Jurnal Pendidikan Manajemen Perkantoran* 4 (1): 49. https://doi.org/10.17509/jpm.v4i1.14954.

Shernoff, David J., Suparna Sinha, Denise M. Bressler, and Lynda Ginsburg. 2017. "Assessing Teacher Education and Professional Development Needs for the Implementation of Integrated Approaches to STEM Education." *International Journal of STEM Education* 4 (1): 1–16. https://doi.org/10.1186/s40594-017-0068-1.

Taylor, Peter Charles. 2018. "Enriching STEM with the Arts to Better Prepare 21st Century Citizens." *AIP Conference Proceedings* 1923. https://doi.org/10.1063/1.5019491.

Teo, Tang Wee, and Kaijie Justin Ke. 2014. "Challenges in STEM Teaching: Implication for Preservice and Inservice Teacher Education Program."*Theory into Practice* 53 (1): 18–24. https://doi.org/10.1080/00405841.2014.862116.

Ulmi, F. (2017). *Tahap Design (Perancangan) Lembar Essay Assessment Berbasis Creative Problem Solving (CPS) untuk Meningkatkan Kemampuan Berpikir Kreatif Peserta Didik dalam Pembelajaran Fisika di SMA*. *3*, 451–461.

Watermeyer, Richard, and Catherine Montgomery. 2018. "Public Dialogue with Science and Development for Teachers of STEM: Linking Public Dialogue with Pedagogic Praxis." *Journal of Education for Teaching* 44 (1): 90–106. https://doi.org/10.1080/02607476.2018.1422621.

Winarni, Juniaty, Siti Zubaidah, and Supriyono Koes H. 2016. "STEM: Apa, Mengapa, Dan Bagaimana." *Prosiding Seminar Nasional Pendidikan IPA Pascasarjana UM*.

Wu, Chia-chun, Cheng-ying Yang, and Min-shiang Hwang. 2019. "The Design and Application of a Web-Based Teacher Evaluation System for STEM Education," no. 500: 1–11. https://doi.org/10.1177/0020720919852783.

Yehudit Judy Dori, Zemira R.Mevarech, and Dale R.Baker. 2018. *Cognition, Metacognition, and Culture in STEM Education: Learning, Teaching and Assessment*.

Zervas, Panagiotis, Eleftheria Tsourlidaki, Yiwei Cao, Sofoklis Sotiriou, and Demetrios G Sampson. 2016. "A Study on the Use of a Metadata Schema for Characterizing School Education STEM Lessons Plans." *Journal of Computing in Higher Education.* https://doi.org/10.1007/s12528-016-9113-1.