Exploring STEM Learning in Lower Grade of Primary Education

Putu Nanci Riastini[1], I Nengah Suparta[2], Luh Putu Sri Lestari[3], Ade Dwi Utami[4]

[1] Universitas Pendidikan Ganesha, Indonesia;
[2] Universitas Pendidikan Ganesha, Indonesia;
[3] Universitas Pendidikan Ganesha, Indonesia;
[4] Universitas Negeri Jakarta

Abstract

Studying STEM is essential for students, even the lower grades of elementary school, to develop 21st century skills from a young age. Unfortunately, research regarding teaching STEM to younger students and professional training models for educators to integrate STEM in elementary schools is lacking. This research aims to determine the application of STEM in lower elementary grades; examine the factors that influence the effectiveness of STEM implementation in lower elementary grades; investigate strategies used to introduce STEM in lower elementary grades; and assessing STEM evaluation methods to increase the effectiveness of STEM implementation in the lower elementary grades. The initial phase of the project will involve conducting exploratory research on STEM in elementary school classrooms. This research will use a combination of approaches, starting with quantitative research and continuing with qualitative research. Surveys will be used for quantitative data collection, while interviews, focus group discussions, and observations will be used for qualitative data collection. Quantitative data analysis will involve descriptive and inferential statistics. Qualitative data analysis will involve content analysis followed by the application of triangulation. The research results show that STEM is very necessary to improve elementary school students' thinking, STEM can be combined with games to attract students' attention. A simple example of applying STEM is a simple project, so it can train students to work in groups which will have an impact on their social emotional abilities. The results of this research can be used as a reference for future STEM applications

Keyword: STEM; STEM based model of teaching; lower grade of primary education

1. Introduction

The integration of science, technology, engineering, and mathematics, known as STEM education, has become a focal point in global educational discussions (Bishop, Gavel, Chapin, Fernandez, & Allard, 2023; Cortés, Guix, & Carbonell, 2021). The integration of concepts and practices from four disciplines is a key aspect of this interdisciplinary approach. Problem-solving, critical thinking, creativity, and collaboration are all emphasized in STEM education (Yalçın & Erden, 2021). The purpose of STEM education is to equip students with the science, technology, engineering, and math skills that employers will value highly in the workforce of the twenty-first century (Tytler, 2020). Inquiry-based, experiential learning is a common feature of STEM education, which pushes students to apply their learning to real-world issues and challenges (Öztürk, 2024). Stated differently, this methodology equips pupils to meet the demands of the twenty-first century.

It is crucial to introduce STEM concepts early on, especially in the lower elementary school grades (Alam, 2022). Because STEM courses may provide a strong foundation in analytical, problem-solving, and critical thinking skills—all necessary for success in future academic and professional endeavors—they are important for STEM education in the lower grades of primary education (Novianti, Nitiasih, & Riastini, 2023). Furthermore, since the world depends more and more on innovation and technology, it is imperative that young students develop STEM competencies at a young age in order to better prepare them for life in an increasingly technologically advanced and complicated society (Wu, Huang, Liu, & Chiang, 2024).

Actually, it was difficult to successfully incorporate STEM ideas into elementary education's lower grades (Dong, Wang, Yang, & Kurup, 2020). For instance, traditional methods of teaching STEM courses frequently concentrate on discrete subject areas and do not give students the chance to engage in experiential, inquiry-based learning. Furthermore, it's possible that educators lack the tools and training needed to successfully integrate STEM education into their classrooms (Lo, 2021; Riastini et al., 2021). The lack of professional development programs that prepare teachers to design and teach STEM in the classroom was the reason for this. Regretfully, because there isn't a STEM-based teaching model that they have encountered while attending university, prospective instructors did not acquire the abilities necessary to teach STEM (Rusnilawati et al., 2022). They also had no idea how to implement it.

A substantial body of research on STEM-based learning has emerged in response to these problems. For instance, Toto, Yulisma, and Amam's research from 2021 focused on improving teacher preparation for integrating STEM and their comprehension of it. As an additional illustration, one study sought to ascertain how well STEM education affected students' comprehension and attitudes about science (Thahir et al., 2020). The goal of Starr et al.'s research Starr et al., (2020) is to ascertain what experiences students have while integrating STEM into their classroom instruction. Finally, Yang & Baldwin's research (2020) sought to provide examples of technology-use methods in STEM classroom contexts. However, no teacher nor research was conducted on developing and executing creative STEM-based teaching approaches in the lower elementary grades. However, there hasn't been any study on creating and executing creative STEM-based teaching models in primary education's lower grades, nor has there been any professional development for teachers specializing in STEM implementation. For this reason, this model needs to be created.

Investigating STEM education in the lower elementary school grades is a prerequisite for developing the model. The application of STEM in lower elementary school grades, factors influencing its effectiveness, the strategies used to implement STEM in the grades, and the methods by which teachers assess the effectiveness of STEM implementation for learning in lower elementary school grades are some of the topics that require further investigation. The information will serve as a starting point for creating a STEM learning strategy for primary school students in the lower grades.

2. Literature Review

2.1 STEM

There is a lack of research on the creation and application of creative STEM-based learning paradigms in lower grade basic education. Thus, the use of models to solve problems is what makes this research novel. On the other hand, STEM research has focused on teacher training to enable them to incorporate STEM into the classroom. Application of STEM to early childhood classroom teaching and learning activities was the subject of additional STEM study (Wan, Jiang, & Ying Zhan, 2021). The use of STEM to blended learning for high school students has been the subject of additional research (Ardianti, Sulisworo, Pramudya, & Raharjo, 2020). Additionally, STEM is utilized in middle school instruction to help pupils develop their critical thinking abilities in seventh grade (Hacioglu & Gulhan, 2021). According to other studies, STEM is used in blended learning for third, fourth, and fifth graders (Seage & Türegün, 2020).

In general, STEM implementation and training were the emphasis of STEM research (Toto, Yulisma, & Amam, 2021). Another study trained high school teachers in STEM subjects (Kelley et al., 2020). In addition, studies have been conducted on the topic of STEM reflection for effective learning in sixth, seventh, and eleventh grade classrooms (Yildirim et al., 2020). A different study examined how well STEM education may enhance students' learning outcomes and critical thinking abilities in the tenth grade (Minarti, Dzakiy, & Nilautama, 2023). According to other research, STEM is used in high school projects (Samsudin, Jamali, & Ebrahim, 2020). Additional studies support the value of STEM and mobile augmented reality in fourth grade (Wahyu, Suastra, Sadia, & Suarni, 2020).

Nevertheless, no studies have been discovered that utilize the STEM learning model for STEM implementation in lower elementary school grades or the professional development training model for STEM implementation in lower elementary school grades. In order to equip the next generation with 21st century abilities, the project aims to create a STEM-based teaching model that can be implemented successfully in lower primary school grades. Additionally, a professional development training model for these teachers will be developed.

2.2 Lower Grade of Primary Education

Lower grade of primary education refer to children who are in the early classes of primary school, usually 1st to 3rd grade. At this stage, students are still in the initial phase of formal education, where they begin to learn basic skills such as reading, writing, and counting, as well as introducing other basic concepts in a variety of subjects. Meanwhile, the age range of the elementary school students is six or seven years to eight or nine years. (Tharaba, 2020). At this age the full potential and character of the child should be developed to the maximum extent possible. Character development of junior students can be done by developing learning that

allows students to become more active, honest, and caring for the environment (Sinta, Malaikosa, & Supriyanto, 2022).

Lower grade of primary school need a learning medium that can deliver material in a concrete way. (Ahmad & Mustika, 2021). Through the learning media, then the learning process that students experience can become more meaningful. In the process of learning, the students of the lower class are very happy with some things, namely, playing, moving, working in groups, and acting something in person (Agustina, 2017). Then the teacher should facilitate the student with a pleasant learning.

One of the most suitable approaches for junior students is STEM. (Science, Technologi, Engineering, and Mathematics). This approach combines learning science, technology, engineering, and mathematics in the form of interactive and game-based activities, so that children can learn while playing. STEM can be implemented using simple experiments, math games, and small projects relevant to everyday life.

3. Material and Method

3.1 Design Study

To fully analyze a research subject, this study will employ mixed methodologies, which combine qualitative and quantitative approaches. The study will commence with a quantitative phase aimed at collecting numerical data and identifying patterns or trends in the application of STEM in lower primary school grades. Surveys will be used in this phase. Probability sampling techniques are employed in the sampling process to guarantee the representativeness and generalizability of quantitative data. A qualitative phase is used as a follow-up to the quantitative phase to investigate settings, underlying causes, or motives. Focus groups, observations, and interviews will all be used as methods. Purposive sampling will be used in the sampling process, with participants chosen based on their ability to offer rich, varied insights pertinent to the study issue.

3.2 Data Analysis

Both quantitative and qualitative analysis will be used for data analysis. To evaluate quantitative data and find relationships, quantitative analysis will use statistical approaches like inferential statistics analysis and descriptive statistics. Thematic analysis will be used in qualitative analysis to understand the data and find the explanations. Findings from the quantitative and qualitative phases will be compared using data triangulation to determine any convergence, divergence, or complementarity.

4. Discussion

The STEM education approach is very important for early elementary school children because it can help them build creativity, problem solving, and critical thinking skills from an early age. This is in line with previous research which states that learning using the STEM approach is effective in improving the critical thinking skills of elementary school students in Wae Ri'i District (Davidi, Sennen, & Supardi, 2021). Other research also states that STEM can increase student activity and develop students' skills for critical thinking, problem solving, and collaboration (Suranti & Wahyuningsih, 2023). The effectiveness of student learning outcomes, especially the critical thinking skills of elementary school students, can be improved

through STEM (Handayani, 2020). Children are in a phase of rapid cognitive development at the early elementary school age. Therefore, introducing STEM ideas can foster their curiosity about the outside world.

STEM must be implemented in an interactive, fun, and relevant way to everyday life for children in the early elementary grades. This is in line with the results of previous research which showed that STEM learning delivered in an interesting way, such as using photos or videos, can make students more critical and able to convey information obtained in the real world (Meinarni, 2022). STEM implementation can be done with a combination of traditional outdoor learning games as a learning innovation (Artobatama, 2018; Nurjaman, Hamdu, & Elan, 2018). STEM which is designed in the form of a game was very suitable for the development of students in the early elementary grades. The combination of learning while playing can increase their enthusiasm for learning.

Some ways to implement STEM that can be done involve games, simple experiments, and problem-based projects that allow children to play and learn. The implementation of ethno-STEM also provides positive results on student learning outcomes (Al Idrus, 2022). An example of applying STEM in learning was carried out by simple science experiments. Experiments on making volcanoes from materials available at home, math games that involve counting everyday objects, or engineering projects, such as making and building small bridges with popsicle sticks and glue, were some examples of applying STEM in the early grades.

The application of STEM had positive social-emotional effects. This is in line with the results of previous research which showed that technology which is part of STEM plays an important role in overcoming social competence in emotional learning (Flynn et al., 2024). Early elementary school children learned to work together in teams, communicate, and accept failure as part of the learning process in STEM activities. For example, when children worked together on a simple project, they learned how to share ideas, listen to friends, and create strategies together. They also learned important life skills such as remaining determined and not giving up when faced with difficulties. When children successfully complete a STEM assignment or project, they were more confident and feel satisfied and proud. Previous research showed that STEAM-based social environmental learning for kindergarten children improved their learning outcomes (Purwaningsih, Munawar, & Hariyanti, 2022). Overall, STEM not only improves children's academic abilities but also helps their social-emotional development, preparing them to become better prepared people for the future.

5. Conclusion, Implication, and Recommendation

STEM education is essential for early elementary school children as it enhances creativity, problem-solving, and critical thinking skills. Research showed that STEM improves critical thinking, student engagement, and collaboration. Implementing STEM through interactive games, simple experiments, and problem-based projects makes learning enjoyable and stimulates curiosity. Additionally, STEM activities positively impact social-emotional development, fostering teamwork, communication, perseverance, and confidence. Overall, STEM education not only boosts academic skills but also supports children's holistic development, preparing them for future challenges. The results of this research can be used as a reference for implementing STEM in lower elementary school classes. Future researchers can

conduct research for STEM model for lower grade elementary school students to expand the theory of STEM in elementary education.

6. References

Agustina, D. A. (2017). Model Pembelajaran Untuk Mengenalkan Kewirausahaan Pada Siswa Sekolah Dasar Kelas Rendah. *Bangun Rekaprima*, *3*(2), 43–56. https://doi.org/10.32497/bangunrekaprima.v3i2.866

Ahmad, F., & Mustika, D. (2021). Problematika Guru dalam Menerapkan Media pada Pembelajaran Kelas Rendah di Sekolah Dasar. *Jurnal Basicedu*, *5*(4), 2008–2014. https://doi.org/10.31004/basicedu.v5i4.1056

Alam, A. (2022). Educational Robotics and Computer Programming in Early Childhood Education: A Conceptual Framework for Assessing Elementary School Students' Computational Thinking for Designing Powerful Educational Scenarios. *International Conference on Smart Technologies and Systems for Next Generation Computing (ICSTSN)*, 1–7. https://doi.org/10.1109/ICSTSN53084.2022.9761354

Ardianti, S., Sulisworo, D., Pramudya, Y., & Raharjo, W. (2020). The Impact of the Use of STEM Education Approach on the Blended Learning to Improve Studenat's Critical Thinking Skills. *Universal Journal of Educational Research*, *8*(3), 24–32. https://doi.org/10.13189/ujer.2020.081503

Artobatama, I. (2018). Pembelajaran STEM Berbasis Outbond Permainan Tradisional. *Indonesian Journal of Primary Education*, *2*(2), 40–47. https://doi.org/10.17509/ijpe.v2i2.15099

Bishop, B. W., Gavel, S., Chapin, E., Fernandez, P., & Allard, S. (2023). Science, technology, engineering, and mathematics (STEM) liaison librarians: Perspectives on functions and frequencies for serving academic researchers. *Library & Information Science Research*, *45*(4), 101265. https://doi.org/https://doi.org/10.1016/j.lisr.2023.101265

Cortés, J. D., Guix, M., & Carbonell, K. B. (2021). Innovation For Sustainability in the Global South: Bibliometric Findings From Management & Business and STEM (Science, Technology, Engineering and Mathematics) Fields in Developing Countries. *Heliyon*, *7*(8). https://doi.org/https://doi.org/10.1016/j.heliyon.2021.e07809

Davidi, E. I. N., Sennen, E., & Supardi, K. (2021). Integrasi Pendekatan STEM (Science, Technology, Enggeenering and Mathematic) Untuk Peningkatan Keterampilan Berpikir Kritis Siswa Sekolah Dasar. *Scholaria: Jurnal Pendidikan Dan Kebudayaan*, *11*(1), 11–22. https://doi.org/10.24246/j.js.2021.v11.i1.p11-22

Dong, Y., Wang, J., Yang, Y., & Kurup, P. M. (2020). Understanding Intrinsic Challenges to STEM Instructional Practices for Chinese Teachers Based on Their Beliefs and Knowledge Base. *International Journal of STEM Education*, *7*(47). https://doi.org/https://doi.org/10.1186/s40594-020-00245-0

Flynn, K. S., Li, L., Huang, C.-W., Patel, R., Luttgen, K., Yang, S., & Chow, E. (2024). Leveraging Technology to Address Social-Emotional Learning during the Pandemic: Findings from an Efficacy Trial. *Social and Emotional Learning: Research, Practice, and Policy*. https://doi.org/10.1016/j.sel.2024.100045

Hacioglu, Y., & Gulhan, F. (2021). The Effects of STEM Education on the Students' Critical

Thinking Skills and STEM Perceptions. *Journal of Education in Science, Environment and Health*, *7*(2). https://doi.org/https://doi.org/10.21891/jeseh.771331

Handayani, F. (2020). Building Students' Critical Thinking Skills through STEM-Based Digital Literacy during the Pandemic Period Covid 19. *Jurnal Cendekiawan*, *2*(2), 69–72. https://doi.org/10.35438/cendekiawan.v2i2.184

Kelley, T. R., Knowles, J. G., Holland, J. D., & Han, J. (2020). Increasing high school teachers self-efficacy for integrated STEM instruction through a collaborative community of practice. *International Journal of STEM Education*, *7*(14). https://doi.org/https://doi.org/10.1186/s40594-020-00211-w

Lo, C. K. (2021). Design Principles for Effective Teacher Professional Development in Integrated STEM Education. *Educational Technology & Society*, *24*(4), 136–152. Retrieved from https://www.jstor.org/stable/48629251

Meinarni, W. (2022). Implementasi Model Pembelajaran STEM Dalam Pembelajaran Matematika di SD. *JEMARI (Jurnal Edukasi Madrasah Ibtidaiyah)*, *4*(2), 109–114. https://doi.org/10.30599/jemari.v4i2.1725

Minarti, I. B., Dzakiy, M. A., & Nilautama, D. (2023). The Effect of STEM (Science, Technology, Engineering, and Mathematics) Based Learning Approach on Critical Thinking Skills and Cognitive Learning Outcomes of Class X SMA Negeri 1. *At-Tasyrih: Jurnal Pendidikan Dan Hukum Islam*, *8*(2), 126–136. https://doi.org/https://doi.org/10.55849/attasyrih.v8i2.151

Novianti, B. A., Nitiasih, P. K., & Riastini, P. N. (2023). Study Of STEM-Based Learning Against 4C Skills (Critical, Creative, Communication, and Collaboration) In Science. *Jurnal Ilmiah Profesi Pendidikan*, *8*(3), 1917–1921. https://doi.org/https://doi.org/10.29303/jipp.v8i3.1455

Nurjaman, A. I., Hamdu, G., & Elan, E. (2018). Pengembangan Multimedia Interaktif Pelaksanaan Pembelajaran Outdoor Permainan Tradisional Berbasis STEM di SD. *PEDADIDAKTIKA: Jurnal Ilmiah Pendidikan Guru Sekolah Dasar*, *5*(4), 74–84. https://doi.org/10.17509/pedadidaktika.v5i3.12728

Öztürk, A. (2024). Meeting the Challenges of STEM education in K-12 Education through Design Thinking. *Design and Technology Education: An International Journal*, *26*(1), 70–88. Retrieved from https://openjournals.ljmu.ac.uk/DATE/article/view/1232.

Purwaningsih, P., Munawar, M., & Hariyanti, D. P. D. (2022). Analisis Pembelajaran Lingkungan SosialB erbasis STEAM pada Anak Usia Dini. *MURHUM : Jurnal Pendidikan Anak Usia Dini*, *3*(1), 13–23. https://doi.org/10.37985/murhum.v3i1.68

Riastini, P. N., Mahayanti, N. W. ., SUryadarma, I., & Wangid, M. . (2021). Barriers to Elementary School Teachers' Professional Practice: Teachers' Voice. *İlköğretim Online*, *20*(1). https://doi.org/10.17051/ilkonline.2021.01.101

Rusnilawati, Taufik, H. M., Azzahro, H. A., Ummi, T., Rahma, K. R., Senjawani, P. R., … Sujalwo. (2022). Pelatihan Flipped Learning dengan Pendekatan STEM di SD Muhammadiyah 22 Sruni Surakarta. *Buletin KKN Pendidikan*, *4*(2), 108–122. Retrieved from https://www.academia.edu/download/108359802/8224.pdf

Samsudin, M. A., Jamali, S. M., & Ahmad Nurulazam MD Zain Ebrahim, N. A. (2020). The Effect of STEM Project Based Learning on Self-Efficacy among High-School Physics

Students. *Journal of Turkish Science Education*, *16*(1), 94–108. Retrieved from https://papers.ssrn.com/sol3/papers.cfm?abstract_id=3574024

Seage, S. J., & Türegün, M. (2020). The Effects of Blended Learning on STEM Achievement of Elementary School Students. *International Journal of Research in Education and Science*, *6*(1). Retrieved from https://eric.ed.gov/?id=EJ1231349

Sinta, L., Malaikosa, Y. M. L., & Supriyanto, D. H. (2022). Implementasi Penguatan Pendidikan Karakter pada Siswa Kelas Rendah di Sekolah DasarImplementasi Penguatan Pendidikan Karakter pada Siswa Kelas Rendah di Sekolah Dasar. *Jurnal Obsesi : Jurnal Pendidikan Anak Usia Dini*, *6*(4), 3193–3202. https://doi.org/https://doi.org/10.31004/obsesi.v6i4.2326

Starr, C. R., Hunter, L., Dunkin, R., Honi, S., Palomino, R., & Leaper, C. (2020). Engaging in science practices in classrooms predicts increases in undergraduates' STEM motivation, identity, and achievement: A short-term longitudinal study. *Journal of Research in Science Teaching*, *57*(7), 1093–1118. https://doi.org/https://doi.org/10.1002/tea.21623

Suranti, N. M. Y., & Wahyuningsih, B. Y. (2023). Project Based Learning dengan Pendekatan STEM pada Pendidikan Sekolah Dasar. *Indonesian Journal of Elementary and Childhood Education*, *4*(4), 141–148. Retrieved from https://journal.publication-center.com/index.php/ijece/article/view/1587

Syarifa Wahidah Al Idrus. (2022). Implementasi STEM Terintegrasi Etnosains (Etno-STEM) di Indonesia: Tinjauan Meta Analisis. *Jurnal Ilmiah Profesi Pendidikan*, *7*(4), 2370–2376. https://doi.org/10.29303/jipp.v7i4.879

Thahir, A., Anwar, C., Saregar, A., Choiriah, L., Susanti, F., & Pricilia, A. (2020). The Effectiveness of STEM Learning: Scientific Attitudes and Students' Conceptual Understanding. *Journal of Physics: Conference Series*, *1467*(1).

Tharaba, M. F. (2020). Mencari Model Pendidikan Karakter Di Sekolah. *J-MPI (Jurnal Manajemen Pendidikan Islam)*, *5*(1), 66. https://doi.org/10.18860/jmpi.v5i1.8750

Toto, T., Yulisma, L., & Amam, A. (2021). Improving Teachers' Understanding and Readiness in Implementing STEM through Science Learning Simulation. *Indonesia Journal of Science Education*, *10*(2), 303–310. https://doi.org/https://doi.org/10.15294/jpii.v10i2.27509

Tytler, R. (2020). STEM Education for the Twenty-First Century. *Integrated Approaches to STEM Education*, 21–43. https://doi.org/https://doi.org/10.1007/978-3-030-52229-2_3

Wahyu, Y., Suastra, I. W., Sadia, I. W., & Suarni, N. K. (2020). The Effectiveness of Mobile Augmented Reality Assisted Stem-Based Learning on Scientific Literacy and Students' Achievement. *International Journal of Instruction*, *13*(3), 343–356. Retrieved from https://eric.ed.gov/?id=EJ1259691

Wan, Z. H., Jiang, Y., & Ying Zhan. (2021). STEM Education in Early Childhood: A Review of Empirical Studies. *Early Education and Development*, *32*(7), 940–962. https://doi.org/https://doi.org/10.1080/10409289.2020.1814986

Wu, Z., Huang, L., Liu, Y.-K., & Chiang, F.-K. (2024). Developing a Framework of STEM Literacy for Kindergarten Children. *Research in Science and Education*, 1–23. https://doi.org/https://doi.org/10.1007/s11165-024-10157-6

Yalçın, V., & Erden, Ş. (2021). The Effect of STEM Activities Prepared According to the Design Thinking Model on Preschool Children's Creativity and Problem-Solving Skills. *Thinking SKills and Creativity*, *41*, 100864. https://doi.org/https://doi.org/10.1016/j.tsc.2021.100864

Yang, D., & Baldwin, S. J. (2020). Using Technology to Support Student Learning in an Integrated STEM Learning Environment. *International Journal of Technology in Education and Science*. Retrieved from https://scholarworks.boisestate.edu/edtech_facpubs/239/

Yildirim, B., Sahin-Topalcengiz, E., Arikan, G., & Timu, S. (2020). Using Virtual Reality in the Classroom: Reflections of STEM Teachers on the Use of Teaching and Learning Tools. *Journal of Education in Science, Enviroment and Health*, *6*(3). https://doi.org/10.21891/jeseh.711779