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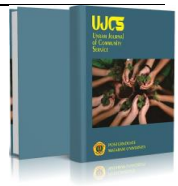

Building Deeper Learning Through STEM Education for Elementary School Teachers

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Abstract: STEM education (Science, Technology, Engineering, and Mathematics) in Indonesia, particularly in Maluku, faces the challenge of a skills gap that impacts economic growth. The goal of this training is to enhance teachers' competencies in integrating STEM and Deep Learning into the learning process. The training program is carried out by the Community Service Team from the Faculty of Teacher Training and Education at Pattimura University to improve teachers' understanding and ability to implement deep learning (DL) in STEM education. The results of the pre- and post-tests showed a significant increase in teachers' understanding and ability to adopt innovative educational approaches. The integration of STEM and DL has great potential to improve the quality of education. Teacher training and collaboration between educational institutions and the community are very important in enhancing the quality of education. Recommendations: (1) continuously improve teacher training, (2) develop curricula that support the integration of STEM and DL, and (3) enhance collaboration between universities and local schools to improve the quality of education and prepare students to face 21st-century challenges. Thus, it is expected to improve the quality of education and enhance students' ability to think critically and solve problems in the technological era.

Keywords: Deep Learing, STEM, STEAM, Island Teacher, 21st Century Skills.

Introduction

Science education, especially at the elementary level, introduces children to various concepts that become increasingly complex, from basic to advanced. The goal of this approach is to build a solid foundation of knowledge, which is crucial for helping students tackle complex scientific situations in the future (Holbrook, 2010; Alberts, 2022). In addition, understanding the physical properties of materials is also important for young students so that they can connect scientific knowledge with everyday experiences and phenomena they encounter firsthand. Furthermore, understanding scientific concepts requires basic skills such as observing, asking questions, making predictions, conducting simple experiments, as well as recording and presenting findings (Kurniawati, 2021; Öztürk et al., 2010). These skills become an important foundation for students to conduct scientific investigations and explorations. Science learning becomes more engaging for young students because they can directly experience the learning process, making abstract concepts more concrete and connected to everyday life (Öztürk et al., 2010). Through activities such as experiments and observations, students can connect the knowledge they acquire with the real world, thereby increasing their curiosity and interest. These activities also often involve teamwork, where students share ideas, collaborate, and learn from each other. This collaboration not only enhances their understanding but also develops their communication and teamwork skills. As a result, students can cultivate a positive attitude

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towards science, improve their critical thinking abilities, and gain a better understanding of scientific concepts (Gizaw & Sota, 2023).

For example, studies from several countries show that traditional teaching practices are still applied. First, science education in Thailand is often criticized for the lack of active student participation. Usually, teachers take the main role in the classroom, giving lectures while students just listen and wait for instructions from the textbook (Yuenyong & Narjaikaew, 2009; Faikhamta et al., 2018). Secondly, a brief review of Dutch medical education shows that about 70% of teaching activities involving instructors consist of lectures to students (Schmidt et al., 2010). A teacher stands at the front of the class, speaking and showing slides while students listen and take notes. Conventional teaching does not promote critical thinking, shows low student attendance, and lacks cognitive engagement. Moreover, the assumption that lectures can effectively cover all essential material is incorrect. Empirical literature also indicates that understanding of what students truly learn through lectures remains limited. The main issue in higher education lies in the information transmission approach, which wrongly assumes that students can learn simply by receiving information directly (Schmidt et al., 2015). Thirdly, in many Asian education systems, including Cambodia, traditional teaching methods mostly focus on memorization and written exams, making the transition to oral presentations very challenging (Tareen et al., 2023). These methods tend to limit students' opportunities to experiment, discuss, or apply knowledge to real-world problems.

Modern education emphasizes the construction of knowledge by students, where the process of discussion and dialogue plays an important role (Boyer et al., 2014). It has been explicitly and repeatedly stated that appropriate learning strategies must be adopted by today's teachers to ensure a sustainable future for various local and global communities around the world (Hermes & Rimanoczy, 2018). In fact, some theorists have even stated that there is a crisis in the global education system that demands a new approach to teaching and learning (Fullan & Langworthy, 2013). This has led to the emergence of several concepts/ideas in the field of education over the past few decades, which have quickly been incorporated into various national curricula. Some examples of these prominent concepts in education are inclusion, democracy, adapted learning, self-regulated learning, collaborative learning, critical thinking, and lifelong learning. The commonality among most of these concepts is that they collectively emphasize the importance of long-term future orientation and higher-order thinking (Kovač et al., 2025).

In order for classroom learning to be effective, a teacher must have extensive and deep knowledge of child development, a variety of teaching methods, and a strong mastery of the subject matter. The concept of deep learning has become a popular and widely recognized term in contemporary educational literature and international policy documents. Deep learning (DL) generally carries a positive connotation and represents a learning strategy that educational institutions should adopt to ensure a sustainable future in modern society. However, the main challenge of DL is the fact that the concept is used in various scientific fields with different definitions, understandings, and applications (Kovač et al., 2025). Next, Mintrop et al., (2022) explain in detail about deep learning. The review shows that the movement towards deeper learning in American schools is a move away from what is often referred to as traditional learning, where teachers provide knowledge to students as empty vessels waiting to be filled. This type of shallow learning (1) relies on memorizing isolated facts or reproducing certain processes that are less relevant to the students' lives, (2) is assessed using closed and unimaginative methods such as multiple-choice tests, and (3) is limited to time and space within the classroom. Students may question whether they will use this learning in real life, which, in turn, undermines their motivation to engage. In contrast, DL begins with and is built upon students' curiosity and inquisitiveness, and continues with them as they leave the classroom and engage with the real world. As explained by the William and Flora Hewlett Foundation, the elements of deeper learning include six key competencies: 1. Master core academic content 2. Think critically and solve complex problems 3. Work collaboratively 4. Communicate effectively 5. Learn how to learn 6. Develop an academic mindset. Deeper learning fosters intrapersonal and interpersonal aspects and is characterized by connections to content areas that go beyond vocabulary and facts to analysis and synthesis. Students engage in authentic activities where they, for example, pose meaningful problems, generate various strategies, and consider which strategies make sense.

In addition, teachers must continuously reflect on DL practices to improve their quality. They also need to create a learning environment that encourages creativity, critical thinking, and problem-solving skills, as well as foster a lifelong learning spirit. Learning that emphasizes deep understanding is expected to foster the development of various important 21st-century skills. Fullan & Langworthy (2014) mention that these skills include creativity, collaboration, communication, critical thinking, independent learning, and global citizenship awareness. Henriksen et al., (2021) added that a lack of creativity can pose a risk of failure in various aspects of life. Students should engage actively and critically with

what they learn. In addition to creativity, collaboration is also an important 21st-century skill that must be developed in students. Laal et al., (2012) explained that collaboration involves the ability to work with others, understand, and appreciate each individual's contributions. The world of work and modern society require collaboration because a team's success is influenced by the actions of each of its members. Independent learning is also an essential 21st-century competence that needs to be fostered in higher education. Vilhunen et al., (2025) describe learning autonomy as a process in which students take full responsibility for their learning activities. Students must be able to determine the most suitable methods and learning resources to achieve the desired goals.

The decision to prioritize basic education or STEM specialization for educators must be made carefully and wisely, taking into account the ultimate goal of shaping individuals who are well-rounded and ready to face the ever-evolving global challenges. The impact of a dedicated educator on elementary school students is not only limited to academic achievement but also shapes their values, life skills, and social interactions, as well as preparing them for future success. Therefore, investing in quality teachers who are committed to empowering the next generation is extremely important, enabling them to reach their full potential and face upcoming challenges (Kotsis, 2025).

One potential solution to address this issue is to implement a STEM education approach. The DL concept refers to an approach aligned with the principles of STEM learning (Science, Technology, Engineering, and Mathematics) that encourages students to understand problems, design solutions, and then evaluate and reflect on their learning process actively (Shin et al., 2018). The implementation of DL integrated with STEM education in innovative learning is a growing approach to addressing the challenges of 21st-century education. Innovative learning design in this context serves as an implementation platform that allows the synergistic integration of DL and STEM principles, making the learning process more contextual, reflective, and transformative (Ramlawati & Yunus, 2021). Studies show that the STEM curriculum results in an 82.5% increase in student learning motivation, a 20% to 35% improvement in programming skills, and a 27.5% increase in collaboration skills. However, challenges such as teacher education and limited technological facilities still exist (Nofirman, 2025).

Several studies indicate that STEM can be a valuable tool for enhancing science education at the elementary school level (Meepat et al., 2024). The integration of STEM-based learning has shown a significant impact on improving the 6C skills (character, citizenship, critical thinking, creative thinking, collaboration, and communication) of elementary school students. Children at the elementary education level are those aged between 6 and 12 years (Bashirian et al., 2018). For elementary school students, the development of the 6C skills is important because at that age, character formation and development are at a critical stage. Developing the 6C skills is very suitable at this level because elementary school students are in an active learning phase, where they will experience growth in mindset and behavior. In addition, having these 6C skills can help children build a strong foundation for their future, ensuring a solid base for elementary school students. For elementary school students to succeed in the future academically, socially, and emotionally, they must develop character skills, citizenship skills, critical thinking skills, collaboration skills, and communication skills (Zainil et al., 2024).

The increasingly complex demands of the 21st century require students to be able to think more deeply. This becomes a challenge for students in Indonesia, especially those at SD Negeri 39 Central Maluku, to develop their abilities. Therefore, training for elementary school teachers at SD Negeri 39 Central Maluku on DL and STEM is very important to enhance teachers' ability to apply this approach in the classroom. This way, students can develop thinking skills and improve their learning outcomes. Teachers need to understand the basic concepts of Deep Learning and STEM as well as how to integrate them into learning, as stated by Lin & Chen (2020) that the implementation of DL in learning can significantly develop students' computational thinking skills. In addition, teachers also need to be equipped with the ability to design DL and STEM-based learning, including the development of relevant questions, so that students can increase their engagement in problem-solving and improve learning outcomes (Thibaut et al., 2018). With the right training, teachers at SD Negeri 39 Central Maluku can improve their ability to apply the DL and STEM approaches in the classroom, allowing students to develop their pedagogical and conceptual skills.

The shortage of certified STEM teachers has been a long-standing problem in the United States and worldwide (Castro-Villarreal et al., 2025). According to Desutter (2017), spatial thinking is a vital component in STEM learning. However, learning environments designed to develop this ability are often inadequate. One of the main obstacles is the lack of pedagogical knowledge among teachers, which hinders the effective integration of STEM education in the classroom (El-Deghaidy & Mansour, 2015). In the current context, the demand for STEM workers continues to increase (Kiazad et al., 2024). Therefore, STEM education is crucial to equip individuals with the skills needed for future job opportunities (Reynante et al., 2020).

Unfortunately, South Africa faces a shortage of individuals choosing careers in technology or science, which impacts the economy due to the lack of skilled labor in strategic fields. This skills shortage issue not only occurs in South Africa but is also common in other countries (Robert N. Charette, 2013), where teachers show a limited understanding of STEM integration, particularly through the use of models (Mafugu et al., 2024). In Indonesia, STEM education is implemented through various learning models, such as project-based learning (PjBL), the 6E model (engage, explore, explain, engineer, enrich, and evaluation), learning based on higher-order thinking skill assessment, inquiry, think-pair-share, problem-based learning (PBL), Android games, as well as learning based on digital books and study books. PjBL is one of the most frequently used methods in the implementation of STEM education in Indonesia (Khotimah et al., 2021). However, according to Permanasari et al., (2021), many teachers do not implement the STEM approach in classroom teaching practices, which results in students having a weak understanding of STEM and its integration.

Method

Community service conducted by the lecturers of the Faculty of Teacher Training and Education at Pattimura University is an annual activity carried out by the Vice Dean 3 for Student Affairs and Alumni. This activity aims to contribute to the community, particularly in the field of education. This year, the community service took place from October 21-23, 2025. This community service activity involves 5 lecturers who are experts in their fields, namely Prof. Dr. Anderson L. Palinussa, M.Pd., Prof. Dr. Marleny Leasa, M.Pd., Efilina Kissiya, S.Pd., M.Hum., Ph.D., Jamaludin, S.Pd., M.Sc., and John Rafafy Batlolona, S.Pd., M.Pd. They collaborated to carry out community service activities centered at SMP Negeri 14 Central Maluku. This activity also involved teachers from SD Negeri 39 Central Maluku, SMP Negeri 14 Central Maluku, and SMK Negeri 4 Central Maluku. This article focuses on the teachers of SD Negeri 39 Central Maluku. Therefore, there were two students involved, namely the Chairperson of the Student Association of the Elementary School Teacher Education Study Program and one member, in delivering the material to the elementary school teachers, Niel Makaruku, who provided the material.

This community service activity is expected to provide significant benefits for the teachers in the region. This activity is a concrete manifestation of the commitment of the Faculty of Teacher Training and Education at Pattimura University to improving the quality of education in the island region, especially in Central Maluku. Through this activity, it is expected that teachers can improve their skills and knowledge in teaching, thus providing quality education to students in the area. In addition, this activity can also strengthen the cooperation between Pattimura University and the community, particularly in the field of education. Thus, community service activities by the lecturers of the Faculty of Teacher Training and Education at Pattimura University are very important and beneficial for the community. These activities are expected to continue to be carried out every year to contribute to the improvement of the quality of education in Indonesia.

The training activity began with a pretest for the teachers to assess their understanding related to deep learning and STEM. A total of 10 questions were given related to DL and STEM. Since the 18th century, assessment methods in the form of pretests and posttests have been used in various fields, including medical-nursing, health, mental health, and education. This method remains commonly used because it is a quick and practical way to assess target groups that have undergone an intervention (Stratton, 2019). Studies show that even though participants may answer pretest questions incorrectly, this can have a positive impact on their learning outcomes. For example, in an experiment conducted by Richland et al., (2009), it was observed that students who took a pre-test before reading a short text were only able to answer 5% of the questions correctly. However, the post-test results of those who took it were better compared to those who did not take the pre-test before reading the text. Similar findings were also obtained by Kornell et al., (2009), who found that students who answered pre-test questions incorrectly and then received feedback ultimately achieved better post-test results compared to those who only read the pre-test questions and answers without doing anything.

After the activities are completed, a posttest is conducted for the training participants using the same questions to evaluate the implementation of the training. This aligns with Majka's (2024) view, which states that posttests are very important in assessment and evaluation. The purpose is to determine whether an intervention or program is effective and impactful. The results of the posttest help decision-makers determine whether a program needs to be continued, modified, or discontinued. This information also helps in allocating resources and improving successful programs. Thus, the posttest allows decision-makers to make the right choices based on accurate data.

Result and Discussion

Community service activities in the form of STEM-based learning training were positively received by the Principal of SMP Negeri 14 Central Maluku, who was

appointed to deliver a speech. He emphasized the importance of innovative learning transformation as an effort to prepare teachers to face the demands of the times, especially in the context of education digitization and the strengthening of pedagogical competencies. Training like this demonstrates a collective commitment to improving the quality of education. This is reflected in the enthusiasm of all the participants present as well as the support from various parties involved. This collaboration has become an important factor in expanding the reach and impact of the training, so that the improvement in the quality of learning not only occurs in one school but also benefits a wider educational network. This activity also demonstrates that improving teacher competence is a fundamental part of human resource development. By equipping teachers with STEM and DL approaches to modern learning, the quality of the teaching and learning process will further improve and be able to produce a generation that is creative, critical, and adaptable to technological developments.

Figure 1. Welcome Speech by the Principal of SMP Negeri 14 Maluku

The training activity on STEM/STEAM-based learning in this DL was officially opened by the Vice Dean 3, who in his speech emphasized how important such training is in the context of improving the quality of education and fulfilling the demands of the Tri Dharma of Higher Education. He conveyed that universities not only function as academic institutions but also have a moral and professional responsibility to contribute to community development through education, research, and community service. In his review, the Vice Dean 3 highlighted that this training is a tangible manifestation of the implementation of the Tri Dharma, particularly in the aspect of community service, where universities are present to provide a direct contribution to improving teachers' competencies in the field. By equipping educators with knowledge about the STEAM approach and modern learning, universities help connect academic theory with real-world practice in education. He also emphasizes the importance of collaboration between universities and schools in improving the quality of learning. According to him, the success of education is not solely the responsibility of schools, but is the result of collaboration among various stakeholders. Therefore, this training serves as a strategic platform for universities to strengthen synergy with educational institutions while also expanding the positive impact of their academic activities. In addition, the Vice Dean 3 emphasized that teachers need to continuously enhance their personal capacity, considering the rapidly evolving technology and teaching methodologies. The STEAM approach integrated with DL is believed to be able to encourage students to think critically, creatively, and be capable of solving complex problems. This aligns with the broader goal of developing superior and adaptive human resources. Thus, the opening of the event by the Vice Dean 3 provides a strong foundation indicating that this training is not merely a technical activity, but an important part of the university's contribution to improving the quality of education and the broader development of society.

Figure 2. Prof. Dr. Anderson L. Palinussa, M.Pd opened the training activities

In today's digital era, education has undergone significant changes. One of the most important aspects of education is the development of students' abilities in the field of STEM. In addition, the rapid development of information technology also requires DL skills for teachers. STEM allows students to think critically and creatively in solving problems, prepares students for the future, and enhances problem-solving abilities. Thus, teachers can improve their teaching skills and create more effective learning. DL allows teachers to analyze

data more effectively, create more personalized learning, and predict students' abilities. Therefore, teachers can enhance their classroom management skills and make learning more interactive. However, the implementation of STEM and DL in schools requires sufficient resources, such as hardware and software, as well as adequate training for teachers. Therefore, providing adequate training and resources is essential for the implementation of STEM and deep learning in schools. This received a positive response from the three school leaders. They hope that all participants can follow along well so that after completion, they can implement it in classroom learning. Furthermore, continuous evaluation is also very important to ensure the effectiveness of STEM and DL implementation in schools. This way, teachers can improve their teaching skills and create more effective learning.

Figure 3. Group photo before the training activities begin with the school leaders

On the topic of STEM/STEAM, students were directly involved in delivering material related to STEM/STEAM, as shown in Figure 4. This material presentation starts from the history of STEM to the needs of the 21st century. Teachers have heard about STEM but find its implementation in teaching and development in learning tools still challenging. The students explained that STEAM education originated in the United States and has been systematically developed. Today, this educational philosophy has been popularized worldwide. The American STEAM education system is relatively mature and its system logic is strong, having established a certain role for other countries to study. The development of American STEAM education has mainly gone through four stages: STS, STSE, STEM, and STEAM. In these four stages, STS represents the embryonic form of STEAM education development; STSE is the result of further exploration of STS; STEM is the most common and well-known stage; STEAM is a relatively new concept, and much research is still needed to promote its development (Yu, 2021).

Figure 4. Presentation of Material by Niel Makaruku

Is STEM Important for Students?

STEM education has been proven to have a positive impact on students, such as improving learning outcomes, developing learning attitudes, technical thinking, and creativity, as well as contributing to the development of 21st-century skills (Yıldırım, 2016; Çeliker, 2020; Oschepkov et al., 2022). Teachers play a key role in facilitating effective STEM learning experiences, as a good understanding of STEM (Keane & Keane, 2016), positive beliefs, and adequate competence (Park et al., 2016) can create a conducive learning environment. As fundamental sources of learning, teachers must be able to create challenging problems and encourage students to actively participate in the learning process (Suebsing & Nuangchalerm, 2021). However, if STEM teachers have limited knowledge and understanding, learning can become restricted and ineffective (Bell et al., 2018). Therefore, preparing teachers to be STEM-ready is crucial through appropriate professional development (PD) activities.

STEM in Indonesia continues to increase, with a significant rise occurring from 2018 to 2019 (Ha et al., 2020). A report by Farwati et al., (2021) found a substantial increase in the implementation of STEM education in Indonesia from 2015-2020, with the highest growth in 2019 and a slight decrease in 2020 due to the COVID-19 pandemic. STEM has been implemented at all levels of education, with high school being the most significant level. In addition, the study also shows that West Java, East Java, and Central Java are the three dominant provinces conducting more than 60% of STEM education research in Indonesia. Farwati et al., (2021) and Ha et al., (2020) It also shows that Indonesian researchers still rarely conduct STEM education research involving education study programs (PST). Several universities in Indonesia have established STEM centers, such as Indonesia University of Education and Semarang State University. Therefore, research and the implementation of STEM education for PST need to be strengthened, and a comprehensive literature review is

required to provide guidance for the implementation and development of STEM in the future in Indonesia. Further research is needed to understand the implementation of STEM education in Indonesia and to improve the quality of STEM education in the future. Thus, it is expected that STEM education can become more effective and efficient in enhancing the quality of education in Indonesia (Nugraha et al., 2023).

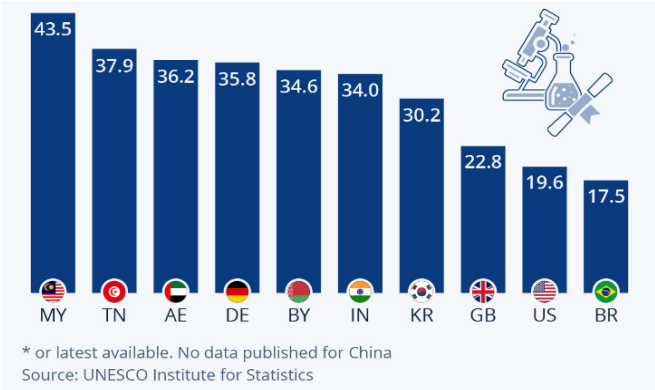
STEM Teaching Methods/Strategies

Although educators implement various strategies to teach STEM, there are several effective methods for spreading the knowledge and skills needed. Agoro (2022) explains that these methods include:

1. Project-Based Learning: This method is considered effective in teaching STEM because students are involved in meaningful long-term projects to develop essential skills. Teachers can directly assess students' progress through these projects.
2. Problem-Based Learning: This approach is student-centered, where they work in groups to solve open-ended problems. This method can teach students about the importance of opportunities and possibilities in STEM. Implementing PBL in schools can provide a conducive learning environment for students and ultimately trigger students to take action in saving the environment. The success of implementing PBL-STEM is determined by the learning experiences in the classroom and other learning environments. This activity is not only aimed at enhancing students' knowledge and literacy but also at training sensitivity, which in turn will trigger students' actions in saving the environment (Widowati et al., 2021).
3. Gamification: The era of game technology has created a student culture that enjoys active engagement and external stimuli. Gamification can provide adequate preparation for students for STEM careers through experiential learning and the formation of learning communities.
4. Collaborative Learning: Exploring STEM career options through collaborative learning can spark students' interest in STEM. Students work together in teams to complete tasks using methods such as Reciprocal Teaching, Peer Tutoring, or Cooperative Learning.

Several studies have shown that these methods can improve the quality of learning and student motivation in STEM. For example, research by Freeman et al., (2008) found that undergraduate students in STEM had better attitudes, motivation, and learning after participating in related courses. The condition of elementary schools in our country is very concerning, making it difficult to find any positive outcomes in achieving STEM education goals, just like in Nigeria and even in Indonesia, which is still learning with limited facilities. Inadequate school facilities, such as damaged buildings or a lack of classrooms, as well as a shortage of basic equipment like tables and chairs. This poor environmental condition has hindered the learning process and weakened the foundation of our education sector. Meanwhile, countries like Japan, China, and South Korea have already moved much further ahead. Students in those countries are able to assemble cell phones and carry out more complex projects, while students in our country are still struggling to find direction and purpose in their lives. The widespread insecurity in this country is also very concerning and can hinder the thought processes needed to develop STEM programs. Therefore, we need to make major changes to improve the quality of our education and provide better opportunities for our students to thrive (Agoro, 2022).

In short, Asian countries and some Middle Eastern countries have a higher proportion of STEM graduates compared to Western countries such as the UK, the US, and Brazil.



Sources: https://www.weforum.org/stories/2023/03/which-countries-students-are-getting-most-involved-in-stem/

Figure 5. Countries with the highest percentage of STEM graduates from their tertiary education graduates.

Figure 5 shows the percentage of STEM graduates relative to the total higher education graduates in selected countries in 2022. Although China is not included in the figure due to the lack of comparative data, China has the highest enrollment and the largest number of STEM graduates in the world (Niancai et al., 2025). In addition, STEM has a short history in China compared to the US; China also leads the world in research and publications, surpassing the US for the first time in 2021 and showing an upward trend (Niancai et al., 2025). Countries with Social Security Administration (SSA) like Ethiopia must recognize the key role of STEM education in creating a competent, motivated, and skilled workforce for the labor market and therefore for national economic development and the achievement of the SDGs (Sebsibe & Abegaz, 2025).

Integration of DL with STEM education for elementary school teachers

A new approach for elementary school teachers requires quite a long adjustment period. Teachers also sometimes complain because the curriculum changes frequently. Especially in the island regions, which receive information more slowly compared to areas in Western Indonesia. STEM has been developed in learning, but at SD Negeri 39 Central Maluku, it is something new for them. In the presentation by Prof. Dr. Marleny Leasa, M.Pd, she provided education about STEM to teachers. STEM is very important in today's era and even helps students to live in the future. STEM in Indonesia still faces many challenges, such as a lack of creativity in teaching, limited access to technology, and disparities in educational opportunities across different regions. Deep learning with a STEM approach can help students understand the connection between concepts and the real world, not just memorize facts. According to Olabe et al., (2018), deep learning can be broken down into three main components: (1) active student involvement in learning; (2) the development of cross-curricular understanding; and (3) critical reflection on their learning. Deep learning challenges students to go beyond traditional classroom practices—to engage in inquiry and innovative thinking. This approach not only builds learning capacity but also fosters a lifelong love of learning; something that is needed in a rapidly changing world (Nofirman, 2025).

Table 1. Comparison of STEM from Various Countries

Country	STEM conditions	Education Policy	Challenges	Requirements
Australia	Big investment, yet student results remain stagnant	Big investment, yet student results remain stagnant	Teaching methods and curriculum	A holistic approach is needed from early childhood education to higher education
India	Ambitious to develop STEM skills, but hindered by infrastructure and teacher quality	Various initiatives to improve science and mathematics skills	Infrastructure and the shortage of qualified teachers	There is a need to improve infrastructure and teacher quality
Indonesia	The education system is diverse, and integrating STEM into the national curriculum remains challenging	Efforts to integrate STEM into the curriculum	Socioeconomic factors and regional disparities	A more integrated and holistic approach is needed
USA	Recognition of the importance of STEM education, yet challenges in student retention in college-level STEM majors	A program to increase STEM graduation rates in colleges	The need for a more engaging and supportive learning environment	A holistic approach is needed from early childhood education to higher education

Sources: (Sheffield et al., 2018)

Table 1 shows that each country has unique conditions, policies, and challenges in implementing STEM education. Furthermore, the majority of teachers do not know how to use DL for education and they often feel insecure in using ICT in the classroom. This is exacerbated by school curricula, which are often driven by coverage rather than skill development, thus providing little opportunity for students to engage in the exploratory and reflective processes necessary for DL.

Furthermore, Lohakan & Seetao (2024) also highlight the bigger picture, noting that, although large-scale trials with AI devices and programming tools have been successful in some countries, for such initiatives to be scaled up, several systemic issues need to be addressed, such as funding, policy support, and teacher development in Indonesia. Without targeted intervention, the gap between well-funded urban schools and underfunded rural schools is likely to worsen, creating an inequitable model for STEM education.

Figure 6. Presentation of Material by Prof. Dr. Marleny Leasa, M.Pd.

Conclusion

Science and mathematics education at the elementary level is very important in building a strong foundational knowledge for students to face complex scientific situations in the future. This is because science education introduces children to various concepts that gradually become more complex, from basic to advanced. The aim of this approach is to build a solid foundation of knowledge, which is crucial in helping students tackle complex scientific situations in the future. The integration of DL principles in STEM education is very important for effective teaching methodologies. DL emphasizes the construction of knowledge by students, where the process of discussion and dialogue plays a crucial role. Appropriate learning strategies must be adopted by today's teachers to ensure a sustainable future for various local and global communities around the world. Active learning approaches such as project-based learning, problem-solving, and collaborative learning can enhance students' understanding and engagement. Project-based learning allows students to engage in meaningful long-term projects to develop essential skills. Problem-based learning is student-centered, where they work in groups to solve open-ended problems. Professional development and training for teachers are very important for the implementation of DL and STEM approaches in the classroom. Teachers must have extensive and deep knowledge about child development, various teaching methods, and strong mastery of subject matter. They also need to understand the basic concepts of DL and STEM and how to integrate both into learning. Collaboration between educational institutions and the community can also enhance the quality of education and prepare students for real-world challenges. STEM education has been proven to have a positive impact on students, such as improving learning outcomes, developing learning attitudes, technical thinking, and creativity, as well as contributing to the development of 21st-century skills. Thus, science and mathematics education at the elementary level, integrated with DL and STEM principles, can help students develop critical thinking, creativity, and collaboration skills, as well as prepare them to face future challenges. Therefore, investment in quality basic education and teacher professional development is very important to improve the quality of education in Indonesia, particularly in Maluku.

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