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Chapter 1 - Technology Utilisation In Learning (A Case Study Senior High School 3 Simpang Hilir North Kayong Regency, West Kalimantan Province)

Yuda Pratama, Nurtanio Agus Purwanto, Muh Khamid, Agung Prihatmojo, Marwan, Agus Herwanto

Chapter Highlights

- This research aimed to explore how technology was integrated into the educational process at State Senior High School 3 in Simpang Hilir, North Kayong Regency, West Kalimantan Province. The study employed a qualitative approach through a case study framework.
- Data were gathered via interviews and document analysis, with reliability ensured through credibility, dependability, and confirmability checks. Data analysis followed an interactive model, encompassing data collection, organization, presentation, and interpretation.
- Findings revealed that technology use at State Senior High School 3 Simpang Hilir fell into three primary areas: planning as a reference resource, the instructional process as a medium and tool, and assessment as an evaluation resource.
- The study identifies that despite the barriers, the application of technology holds significant potential to enhance learning outcomes, if it is supported by appropriate policies and collaborative efforts from various parties. The recommendations of this study include the development of technological infrastructure, continuous training for teachers, and more effective strategies in overcoming existing obstacles. This finding is expected to be a reference for the development of education policies that are adaptive to technological developments in Indonesia.

Introduction

The swift progression of technology in recent decades has exerted a significant influence on various sectors, including education, where these changes have changed the traditional learning paradigm (Zhang et al., 2022). Digital transformation, characterized by the extensive adoption of information and communication technologies, has created significant opportunities to enhance educational quality and broaden access to knowledge (Abad-Segura et al., 2020). This change not only changes the way students interact with learning materials, but also transforms the role of educators in facilitating the learning process. The internet, as a major milestone of technological advancement, has enabled global communication, accelerated the dissemination of information, and supported a more flexible digital-based learning environment (Aldhafeeri & Alotaibi, 2023). The integration of online resources and learning platforms into the world of education also encourages collaborative learning experiences that transcend geographical boundaries (Carpenter & Munshower, 2019; Macintyre et al., 2020). Simultaneously, the development of artificial intelligence (AI) has introduced advanced tools that offer personalized educational content, track student learning progress, and provide data-driven insights into educational practices (Maghsudi et al., 2021).

The Indonesian government sought to incorporate technology within the education system via national policies intended to enhance the quality and equitable distribution of education across the country (Erwin Akib et al., 2020, 2021; Raihani, 2018; Suprapto et al., 2021). Recognizing the growing significance of digital literacy and technological skills in the modern workforce, the Indonesian government emphasized the importance of incorporating technology into teaching and learning within educational institutions (Rayuwati, 2020). This initiative aims to provide students with the necessary skills for success in an increasingly technology-focused world. The particular need to highlight this integration at the upper secondary education level, where students have a higher level of technological skills due to frequent utilization of digital tools like smartphones, tablets, and laptops (Chou & Block, 2019; Ozturk, 2023; Saykili, 2019). Their familiarity with technology gives high school students a better starting point to engage with technology-based learning tools.

While the benefits of technology integration are clear, significant challenges remain, especially in rural areas where infrastructure limitations hinder the effective adoption of educational technologies (Salemink et al., 2017; Wang et al., 2019). These challenges lead to a significant digital gap between urban and rural schools, where rural areas frequently lacking the resources needed to fully implement technology in educational practices (Lembani et al., 2020; Philip et al., 2017; Reddick et al., 2020; Wang et al., 2019). As a result, students in these areas may have limited access to digital learning opportunities, which can exacerbate educational inequalities. Addressing this digital divide requires focused efforts to understand the specific barriers faced by rural schools and develop strategies to bridge those gaps. Therefore, research on technology adoption in the context of local wisdom education (Prihatmojo et al., 2024) is essential to identify existing barriers and formulate approaches that can optimize the use of technology to improve learning outcomes and advance educational equity.

The rural school that seeks to integrate technology into its learning environment despite facing considerable challenges (Reddick et al., 2020). The schools with limited resources and undeveloped infrastructure, have to face various obstacles in utilizing technology to support teaching and learning activities effectively (Gul et al., 2023; Sfenrianto et al., 2018). These challenges include inadequate access to high-speed internet, lack of digital learning materials, and lack of professional development opportunities for teachers to use technology effectively in the classroom (Dinc, 2019; Ndibalema, 2022). Understanding the experience of schools such as State Senior High School 3 Simpang Hilir is essential to develop strategies that are appropriate to the local context that can support the adoption of technology in similar rural environments. This case study aims to explore the extent of technology integration in educational practices at State Senior High School 3 Simpang Hilir, the factors that influence technology adoption, and the resulting impact on student engagement and academic outcomes.

This study aimed to provide a comprehensive evaluation of how technology was utilized in various aspects of teaching and learning at State Senior High School 3 Simpang Hilir, including lesson planning, classroom instruction, and student assessment. It also sought to identify specific challenges encountered in these efforts and to assess how these challenges impacted the extent and quality of technology use in the classroom. Additionally, the study examined broader implications for student participation and achievement, considering how technological tools could support active learning and foster a more inclusive educational environment. This research was intended to offer insights into the effective use of technology in rural schools to enhance education quality in Indonesia. The findings were expected to provide policy recommendations promoting equitable access to education and narrowing the digital divide, thus supporting sustainable development in the educational sector.

Method

This study employs a qualitative approach through a case study design to explore the use of technology in learning at State Senior High School 3 Simpang Hilir, located in North Kayong Regency, West Kalimantan. This qualitative approach allows for an in-depth examination of practices and experiences related to technology integration in the context of rural education. The research was conducted from November 2022 to January 2023, with a focus on uncovering a unique phenomenon in a school that faces challenges related to limited technological infrastructure. Research participants include principals, teachers, and students who are directly involved in the learning process, as well as relevant school documents, such as learning implementation plans (RPPs) and technology policies. Participants were selected purposively to ensure the inclusion of perspectives related to the research objectives.

Data collection was carried out using a combination of methods: classroom observation, semi-structured interviews, and document analysis. Classroom observation aims to see firsthand the application of technology in the teaching and learning process, focusing on its role in planning, implementation, and evaluation, as well as its impact on student engagement. Semi-structured interviews are conducted with principals, teachers, and students to explore their experiences and views on the use of technology, the challenges faced, and its impact on learning outcomes. Document analysis includes a review of school policies, learning implementation plans, and assessment results to complete an understanding of the use of technology in educational planning and evaluation.

To ensure the validity and reliability of the data, several strategies were implemented, including triangulation of methods and sources by comparing data from various collection techniques (observations, interviews, and documents) as well as the perspectives of various participants (principals, teachers, and students). Member checking is carried out by asking participants to review preliminary findings to confirm their accuracy and relevance. Researchers also maintain reflectivity by reflecting on potential bias and systematically documenting field records, providing a transparent audit trail throughout the research process.

Data analysis follows a systematic process, starting with data reduction, in which information from observations, interviews, and documents is selected, summarized, and categorized according to themes related to planning, implementation, evaluation, challenges, and impact of technology. The data is then presented in the form of narratives and tables to illustrate emerging patterns and explain the relationships between variables. Finally, conclusions are drawn and verified through comparison with existing theories and previous research, ensuring the validity of the findings by double-checking with raw data.

Ethical considerations were carefully observed throughout this study. Informed consent is obtained from all participants, their identities are kept confidential, and the data is used exclusively for academic purposes. Although these findings are specific to the context of State Senior High School 3 Simpang Hilir and cannot be generalized to all schools in Indonesia, this study offers important perspectives on the adoption of technology in the context of rural education, as well as offers potential implications for similar contexts.

Results

The use of technology became an important factor influencing interactions between teachers and students, as well as the overall learning process. Amid the swift progress in information and communication technology, the education system faced new challenges and opportunities requiring adaptation and innovation. The findings from the research conducted at State Senior High School 3 Simpang Hilir, North Kayong Regency, were as follows:

Utilization of Technology in Learning Planning

The study's findings indicate that integrating technology into lesson planning at State Senior High School 3 Simpang Hilir significantly enhances teaching quality. Through data collection methods such as direct observation, teacher interviews, and document analysis, it was revealed that utilizing online learning platforms, educational applications, and supportive software enables teachers to create more interactive, dynamic, and relevant instructional strategies.

Teachers at this school adapt various audio-visual-based learning media, tutorial videos from

YouTube, and Google Forms in their planning. The use of these tools shows that teachers are not only keeping up with technological developments, but also trying to meet the needs of students by creating more engaging and engaging learning experiences. Personalization of learning is also evident, as teachers can tailor materials and resources to suit each student's level of understanding, increasing the likelihood of achieving optimal learning outcomes. The integration of technology in learning planning has proven to be not only a necessity, but also a necessity in the context of modern education.

Utilization of Technology in the Learning Process

In the learning process, data gathered from observations and interviews reveal a notable shift due to technology use. Teachers' application of software and digital tools has led to a more engaging and interactive learning experience, enabling students to grasp the material more effectively. Additionally, the incorporation of rich visual and audio components has been shown to enhance student comprehension. E-learning platforms like Google Classroom have made remote learning more accessible, providing students with the flexibility to access resources at any time and from any location. The collaborative dimension of learning has also grown, allowing students to interact and work together on projects through online tools. Despite ongoing challenges with access disparities, this study demonstrates that technology integration at State Senior High School 3 Simpang Hilir is pivotal in fostering a more inclusive and adaptable educational environment.

Utilization of Technology in Learning Evaluation

Learning evaluation at State Senior High School 3 Simpang Hilir has transformed thanks to the application of technology, as can be seen from the data obtained through interviews and document analysis. Digital learning management systems make it easier for teachers to create and manage exams online, which speeds up the correction process and provides flexibility in the preparation of questions.

The data shows that the application of technology allows for the implementation of formative evaluations in real-time, where teachers can provide direct feedback to students based on the results of the evaluation that are immediately available. The use of more diverse assessment methods, such as technology-based projects, simulations, and digital portfolios, further enriches the evaluation process and reflects students' abilities and potentials more accurately. In addition, the analysis of the data generated from online evaluations provides in-depth insights into student learning patterns, so that teachers can design more appropriate and personalized learning strategies.

Barriers to Technology Utilization

The results of the study also identified a number of obstacles in the use of technology, which were obtained from interviews with teachers and analysis of school infrastructure conditions. Limited accessibility and adequate infrastructure, such as unstable internet connections and limited technological devices, are major challenges that create a digital divide between students who have access and those who don't.

The limitations of teachers' knowledge and skills in using technology were also identified as significant obstacles. Many teachers at State Senior High School 3 Simpang Hilir are not used to or lack adequate training from the Education and Culture Office to integrate technology in their teaching methods. In addition, financial constraints associated with limited budgets are a serious obstacle to investment in educational technology hardware and software.

Discussion

The integration of technology in education, particularly at State Senior High School 3 Simpang Hilir, has brought about substantial changes across multiple facets of the learning process. This study’s findings affirm that technology goes beyond being merely a tool; it has become a vital element in crafting effective learning plans. By leveraging online platforms, educational apps, and supporting software, teachers are able to design learning strategies that are both interactive and attuned to students' needs (Alam et al., 2021; Hébert et al., 2021; Shagiakhmetova et al., 2022). In this context, research by Bitirgen et al (2022) underscores the importance of technology adaptation in education to increase student engagement and achieve optimal learning outcomes. With technology, teachers can personalize learning, allowing each student to access the material according to their level of understanding, which contributes to increased motivation and engagement in the learning process (Alamri et al., 2020; Huang et al., 2023; Serrano et al., 2019). This is increasingly relevant in today's educational context, where students are exposed to a variety of abundant sources of information and require the ability to filter and manage such information effectively.

The integration of technology into the learning process at State Senior High School 3 Simpang Hilir has produced a positive impact in creating a dynamic and collaborative learning environment. The data shows that the use of visual and audio elements in learning increases students' grasp, as well as encourages their active participation in the learning process (Afify, 2020; Mayer, 2017). Studies indicate that incorporating technology into learning not only enhances the educational experience but also enhances students' collaborative skills (Lin et al., 2022; Selfa-Sastre et al., 2022; Su & Zou, 2022; Suyantiningsih et al., 2023). Learning technology equipment allows students to be more interactively involved in the learning process (Selfa-Sastre et al., 2022; S. Wu, 2024), The application of technology in learning designs active participants who contribute to collective learning (Qureshi et al., 2023).

However, challenges related to the access gap and adequate infrastructure are still obstacles that need to be overcome (Gonzales et al., 2020). Limited internet access and suboptimal technology devices can create a digital divide among students (Graves et al., 2021), potentially hindering the achievement of equitable learning outcomes. This is reinforced by the geographical condition of North Kayong Regency, where not all regions have equal access to technological infrastructure. In response to these challenges, more proactive policies from local and central governments are needed to improve technological infrastructure in schools in rural areas, including the provision of stable internet access and adequate devices for students and teachers. With the right efforts, it is hoped that this gap can be minimized, so that all students have the same opportunity to benefit from technology in education. So integrated solution measures, such as improving technology accessibility, teacher training programs, and collaborations with technology companies, must be implemented to create a more inclusive and modern learning environment (Martín-Gutiérrez et al., 2017).

On the other hand, the findings of this study also highlight that integrating technology into learning evaluation has transformed assessment into a more efficient and responsive process. Through the use of digital learning management systems, teachers were able to conduct evaluations online, offering enhanced flexibility in question design and significantly accelerating the feedback process for students (Yurtseven Avci et al., 2020). This aligns with the studies which suggest that technology-based assessment methods improve the accuracy of evaluations and allow educators to provide more comprehensive feedback to students (Al-Taweel et al., 2021). Moreover, the application of technology in evaluations facilitates a more sustainable learning environment (Brown et al., 2017), enabling students to directly access their evaluation results and feedback. This accessibility empowers students to identify their academic strengths and weaknesses more effectively, fostering self-directed learning and encouraging them to take a proactive role in their educational progress. As a result, the technology-enhanced evaluation approach not only contributes to the improvement of student performance but also supports a continuous and reflective learning experience that adapts to each student's unique needs.

Although the implementation of technology in evaluation offers numerous benefits, challenges related to teacher training and access to technological resources remained significant concerns (Ferri et al., 2020). A substantial number of teachers reported feeling unprepared to utilize technology effectively for assessment purposes, which hindered the optimal use of technology-based evaluation tools and impacted the overall efficacy of these assessments (Kurt, 2019). This lack of familiarity was frequently attributed to insufficient training support from educational authorities, leaving many teachers without the confidence needed to fully implement these tools in their evaluation practices (Shatunova et al., 2018).

Without appropriate support, teachers may struggle to adapt to technological demands, leading to inconsistent application and, consequently, less reliable assessment outcomes. Hence, establishing a structured, continuous training program is essential to equip teachers with the necessary technological skills and confidence, allowing them to leverage digital evaluation tools more effectively. Such training initiatives should include hands-on practice, access to resources, and follow-up support to ensure teachers develop both proficiency and adaptability in integrating technology into the evaluation process, ultimately enhancing the quality and responsiveness of student assessments.

Thus, the use of technology in education at State Senior High School 3 Simpang Hilir provides important insights on ways to incorporate technology into learning planning, processes, and evaluations. Despite the challenges faced, the results of this study confirm that the use of technology has great potential to improve the quality of education, as long as it is balanced with adequate support from the government and other stakeholders. To achieve more optimal results, it is important for educational institutions to continue to improve technological infrastructure and provide the necessary training for teachers so that they can make the most of technology within the educational process.

The formulation of policies that facilitate the integration of technology in education is urgently needed to establish a learning environment that is inclusive and fair (Mahapatra, 2020). Commitment of all parties, including the government, schools, and the community, it is hoped that technology can be used effectively to improve the quality of education in Indonesia (Salsabila et al., 2021). This research is expected to be a reference for the development of education policies that are more adaptive to technological developments and support the achievement of better learning outcomes in the future.

Conclusion

This study shows that incorporating technology has a markedly positive effect on improving the quality of education, particularly at State Senior High School 3 Simpang Hilir, located in a rural area. The implementation of technology has proven effective in enhancing the quality of lesson planning, delivery, and evaluation through strategies that are increasingly interactive and attuned to the needs of students. However, challenges such as access disparities, limited teacher knowledge of technology, and financial constraints remain obstacles that need to be addressed to ensure that the benefits of technology can be equitably experienced by all students. This research provides a foundation for developing more effective strategies to integrate technology in education in rural areas, emphasizing the importance of synergy among various parties, including the government, educational institutions, and the community, in creating an inclusive and high-quality learning environment. Such collaborative efforts are expected to better prepare the younger generation to face the increasingly complex challenges of the digital era, while further research is recommended to explore strategies for overcoming existing barriers and to assess the long-term impact of technology use on student engagement and achievement across diverse educational contexts in Indonesia.

Recommendations

This study strongly recommends the enhancement of technological infrastructure at State Senior High School 3 Simpang Hilir, which includes not only improving internet access but also ensuring the availability of adequate devices and technical support for both students and teachers. Reliable internet connectivity and sufficient access to digital tools are essential to fully integrate technology into the educational experience, enabling more effective and interactive learning processes. In addition, ongoing professional development and training for teachers is essential, equipping them with the skills needed to effectively incorporate technology into their instructional methods and adapt to evolving educational technologies. Addressing existing resource limitations and bridging the digital divide requires the development of more targeted and sustainable strategies, which should be designed through active collaboration among the government, educational institutions, and local communities. Such partnerships will be key in building a supportive infrastructure and fostering a shared commitment to educational progress. These recommendations aim to lay the groundwork for an educational environment that is not only inclusive and equitable but also enhances the quality of learning outcomes, preparing students to thrive in a technology-driven world and ensuring that no student is left behind in the journey towards a more advanced, accessible, and resilient education system.

Notes

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Chapter 2 - The Effectiveness of Using Quick Response (QR) Code in Indonesian Students' Elementary School Textbook Toward Their Learning Outcomes and Motivation in Learning English

Ni'matul Izza

Chapter Highlights

- The integration of Quick Response (QR) codes into students' textbooks has emerged as a promising tool to enhance the effectiveness of language learning. This study explores the effectiveness of integrating Quick Response (QR) codes in elementary school students' textbooks to enhance their English learning outcomes and motivation in the Indonesian educational context.
- The research employed a quantitative approach, utilizing pre and post-tests to evaluate academic performance and a questionnaire to measure students' motivation. The study involved elementary school students and assessed their English learning progress before and after the incorporation of QR codes in the textbooks. The findings revealed a significant improvement in academic performance among students who used QR codes, suggesting a positive correlation between QR code integration and enhanced understanding and retention of English language content. Furthermore, the inclusion of QR codes was found to positively impact students' motivation levels, promoting active engagement and enthusiasm for learning English.
- These results underline the potential of QR codes as a beneficial tool in language education within Indonesian elementary schools, emphasizing improved academic outcomes and heightened motivation among students.

Introduction

In the implementation of Kurikulum Merdeka in Indonesian schools, there is a fundamental change regarding the position of English as a subject in elementary school. According to Angraeni and Yusuf (2022), English was previously considered as a local content subject in elementary schools while in today's curriculum, English has become a compulsory subject at both primary and secondary levels.

Implementing English as a compulsory subject in elementary schools requires teachers to have access to high-quality curriculum materials that align with the prescribed curriculum and are tailored to students' age and developmental stage (Lems, Kristin (2010). Comprehensive textbooks, engaging workbooks, and supplementary materials are essential tools for structured and meaningful English lessons. These resources empower teachers to create a conducive learning environment and equip students with essential language skills for their academic journey and future endeavors. However, Novianti (2023), Kurniati (2021) and Herwiana (2020) stated that the quality of English textbook used in Indonesian elementary schools need some improvement in the representation of cultural contents, particularly local cultures. Moreover, Lestari (2021) and Kaltsum (2019) stated that the position of the English subject in the curriculum and the lack of government preparation for English language learning may also affect students' interest and motivation in learning English. Therefore, it's crucial to provide teachers with high-quality and culturally relevant textbooks, workbooks, and supplementary materials to create a conducive learning environment and motivate students to study English.

Students' engagement is important in English learning, especially for young learners. Martin (2018) stated that students' engagement increases students' satisfaction, enhances students' motivation to learn, reduces the sense of isolation and improves their academic performance. However, according to Pena (2022), the performance of English Language Proficiency (ELP) assessments among young learners in Indonesia was lower during the pandemic than in previous years, especially in grades 1-6 because the closure of schools has effected children's learning and daily lives. Because of that, by understanding the impact of the pandemic on young learner' academic performance in English, teachers can better tailor their teaching methods to meet the needs of their students and provide effective learning opportunities.

Technology is advancing rapidly. Besides being a form of entertainment, it has the potential to be an educational tool. The use of technology in English language teaching has been integrated into teaching and learning processes in Indonesia, especially after the pandemic. Ferlazzo (2019) stated that English teachers can integrate technology into their instruction to enhance the learning experiences of their students, but they need to make wise choices about which tools to use and how to use them. Along with computers, mobile phones have undoubtedly become essential learning tools. In terms of education, mobile phones are as effective as computers. Mobile phones have become a vital component of students' communication skills, helping them find information and access edutainment programs. furthermore, Pham & Lai (2022) stated that young learners spend extra time doing most of their activities on their mobile phones. By using these tools, teachers can shift the focus of mobile phone use from daily life to the classroom. The presence of advanced features in mobile phones, such as cameras, is a contributing factor to mobile learning. This feature allows teacher to design educational materials and textbooks suitable for use through camera phones Therefore, it is now possible to use cameras for teaching and learning. Additionally, Ferlazzo (2019) stated that teachers can use technology to develop the language skills of their students, especially English-language learners.

One of the most appealing aspects of smartphones is the Quick Response (QR) code system, which can be easily accessed. QR codes automatically collect data that can be read by the device. With the advancement of technology, the data in the QR code can be easily to be read by simply putting the smartphone camera and scanning. After the scanning, the code generator will automatically show up on the screen of the camera phone, and we can click to access the contents that contained in the QR code. Al-Ansi (2023) stated that QR code can provide a more immersive and interactive learning experience for students, making learning more engaging and fun.

QR codes in textbooks have the potential to provide students with access to the additional material that is not contained in them, such as videos, audio, web pages, and etc. QR codes can help facilitate and even improve the material in the textbook. For example, students can still watch videos or audios linked by teachers that cannot be presented directly on the book's pages or sheets. It would be more effective and convenient to scan the QR code in the textbook directly. Instead of inserting a "link" to access it, then you have to input the link in the "search engine" on your phone. The possibilities of QR codes in textbooks can provide other information accessible to students that is not contained in them, such as videos, audio, web pages, etc. QR codes can streamline and even enrich the material present in the textbook. For example, students can still access videos or audios embedded by lecturers that cannot be displayed directly on the pages or sheets of the book. It would be more effective and easier to access by scanning the QR code in the textbook immediately. Instead of inserting a "link" to access it, then you have to input the link in the "search engine" on your phone. Another advantage, especially for audio files, is that students can easily listen to the audio through the QR code while reading the text which is provided in the textbook. This activity gives the students two skills: listening and reading in a single click, which Nation and Macalister (2010) call a meaning-focused input approach. This approach involves the chance to learn from both listening and reading.

The use of mobile learning through QR codes was also conducted by Lai et al. (2013). Participants in the study indicated significant interest in using an integrated QR code learning system. Their research also showed that the design of QR codes in courses is very suitable for new learning methods that combine technology with the experience of living a new generation in education and is necessary for future research. In addition, Tan and Chee, (2021) explored students' motivation towards the application of QR codes in pronunciation learning. As a result, their research results found a significant positive change in students' motivation towards the implementation of QR codes in pronunciation learning. Particularly, they also found an increase in motivation in learning pronunciation as students expressed interest in learning.

QR codes have made a great contribution to their use and usefulness. Concrete learning experiences are necessary in the technology learning process. Therefore, QR codes have become an interesting technology, but the early attention is how teachers can use this tool in a creative way to create a more engaged and student-centered learning environment.

The Importance of Using Qr-Code in Education

The appropriate research recognizes QR codes' vital role in transforming the process of learning. It also brings attention to a number of issues that raise questions about its effectiveness. According to Goyal et al. (2016), the digital education system is nothing but education using gadgets, which is how one study explored the idea of QR codes and their benefits to digital education. As a result, the two notions are interwoven. Material technology offers many advantages for education, but there have also been substantial obstacles due to the influx of technologies, security, validity, and the method of accessing digital material. These days, using a digital information system to easily access academic content is comparable to automating education. By addressing the fundamental issues, QR codes provide a cryptographic method for protecting data, including educational materials, videos, homework, tests, and certifications.

Numerous aspects of education, including problem-based learning, are said to be impacted by the use of QR codes. Santoso et al (2019) found that by using QR, students who were supported by QR had significantly better outcomes than those who depended entirely on direct instruction. These benefits were ascribed, according to Leone (2015), to the QR code's use as a tool for individualized, inclusive, and multidisciplinary learning experiences. Chicioreanu et al (2015) added that students specifically claimed that academics have been drowning with hundreds of pages of online content, all of which are so beneficial that they had to view them. On a web page, links are readily clicked to take users to the desired material. However, because of their lengthy and intricate combined string of characters, these linkages are challenging to present to the students in the learning environment. Quick access to information was the original purpose of QR codes, and because to the widespread usage of devices like tablets and smartphones that can scan the square QR, these codes are now much easier to access. The comparatively massive capacity of QR codes for fast decoding and their ability to store a lot of different types of information make them as the popular technologies.

Method

This study aimed to investigate the effectiveness of QR-codes in Indonesian Students' Elementary School Textbook toward their Learning Outcomes and Motivation in Learning English. A quasi-experimental design was used to conduct this study. Two groups as samples were taken in this study as experimental group and control group. They had different treatment in the research later; the experimental class was taught by using an English textbook which contained QR-Codes, while control class had learned English by using textbook without QR-code inside. The research treatment is using QR-code which linked to the audios and videos.

The study was carried out at one of the Islamic Elementary School in Singosari. The population was the 3rd grade, and the sample was 3A which consisted of 30 students as the experimental group and 3C which consisted of 30 students as the control group. Sugiyono (2010) stated that the appropriate sample size in a research was between 30 to 500 respondents. The sample was chosen by nonprobability sampling. Taking samples in nonprobability sampling does not provide opportunities for each member of the population to be selected as a sample. Furthermore, the English textbook which contained QR-Code was chosen because the book has a QR-Code which linked to the attractive audios and videos that can support this study.

Data collection techniques were carried out using documentation to find out students' name, grades and attendance numbers in 3A and 3C; Tests were used to collect data on students' learning outcomes on material that has been taught to students. The tests used in this study were in the form of multiple-choice questions as many as 25 questions for the pretest and 25 questions for the posttest; Questionnaires were used to collect data by asking written questions to be answered in writing by respondents to collect the data of students' motivation. Researcher used a closed-ended questionnaire type with a check list. The questionnaire which has given to respondents totaled 30 questions. The students' learning motivation questionnaire was given twice to the students. The first questionnaire was given at the beginning before learning which aims to determine the level of student learning motivation towards English language learning before treatment. The second questionnaire was given after learning to determine learning motivation after treatment. The learning motivation questionnaire was given to both experimental and control classes. Then, questionnaire designed in Indonesian language to avoid misunderstanding question both of respondent and researcher. Indonesian language is chosen because it is as the national language that could be understood by Indonesian people. If the respondents understood about the questionnaire, the researcher expected to get a valid data and make easier to respondents to fulfill the questionnaire. A likert scale was used to measure the questionnaire instruments; Observation was used to observe the activities during the learning process. All the activities during the learning process were recorded by observation sheets. There were two observations in this study which are, observation for teacher activity and observation for students' activities; Validation was used to obtain the data on the results of expert validation regarding the research instruments used. The research instruments can be used if it gets a valid assessment category. The validation sheets contained in this study are: observation validation sheet, lesson plan validation sheet, questionnaire validation sheet and pretest and post-test question sheets.

To analyze the data, this study used the t-test to see learning outcomes and percentage value analysis to see students learning motivation. Data analysis was processed using the SPSS program. T-test is used at the 5% level or $\alpha = 0.05$ with the following procedures; the average student score, standard deviation, normality test using the Lilliefors test, homogeneity test, and hypothesis testing. The hypotheses to be tested in this study are:
H_0: There is no effect of using Qr-Code on students' English textbook on learning outcomes and students' motivation.

H_a: There is an effect of using Qr-Code on students' English textbook on learning outcomes and students' motivation.

Hypothesis testing criteria H_0 is rejected if $t_{count} > t_{table}$ or H_0 will be rejected if sig. value $<$ 0,05.

Results

This research was conducted at Almaarif 02 Singosari Islamic Elementary School in English subject. This research was conducted using a quasi-experimental type of research by giving tests to two classes of 30 students each, namely 30 students in the experimental class and 30 students in the control class. The test results will then be analyzed descriptively and inferential statistical analysis with paired sample t-test for hypothesis testing.

Pre-Test and Post-Test Analysis on Students' Learning Outcomes

Based on the table above, the mean of experiment pre-test is 75.23, while the mean of experiment post-test is 89.33. The mean of control pre-test is 78.53 and control post-test is 82.97. There was a significant increase in the average score from the pre-test and post-test of the experimental class. Therefore, the use of QR codes in English textbooks can effectively improve students' learning outcomes.

Table 1. The Mean Difference of Control And Experiment Class

	N	Minimum	Maximum	Mean	Std. Deviation
Pre-Test Eksperimen	30	65	82	75.23	4.360
Post-Test Eksperimen	30	76	98	89.33	5.880
Pre-Test Control	30	60	90	78.53	7.205
Post-Test Control	30	71	95	82.97	5.617

Source: research in 2024

For more details, the average data (mean) in the previous table can be represented in the form of a histogram graph as follows:

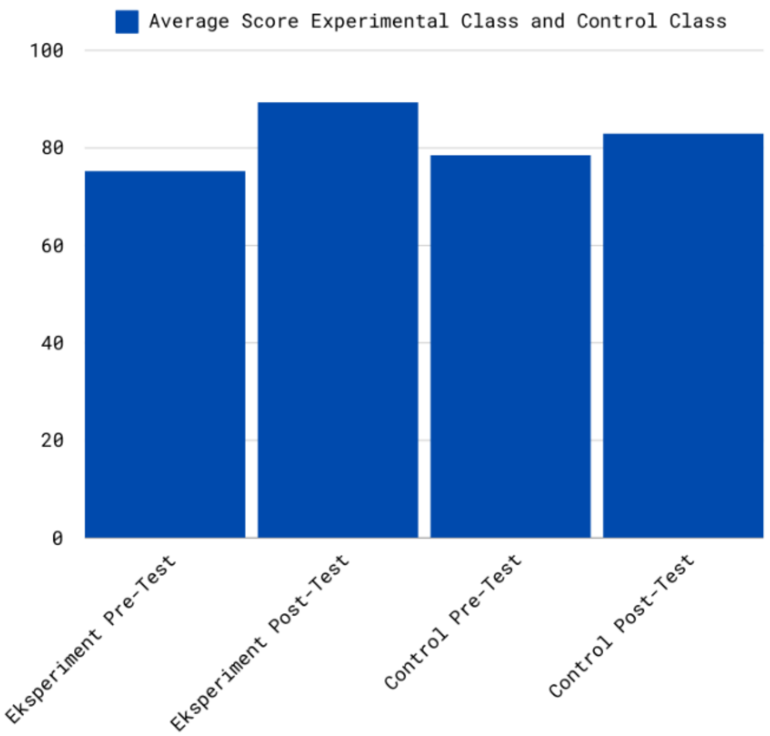

Figure 1. The Mean Difference of Control Class And Experiment Class

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Based on the figure above, it shows an increase in student learning outcomes by comparing the posttest scores in the control class and experimental class which has a significant difference, the difference between the control class is 4.44 and the experimental class is 14.1. It can happen because of the difference in treatment in the experimental class which uses a textbook with QR-Code to access the learning contents and the control class using a textbook which is text based and only provides vocabularies and exercises.

Motivation Questionnaire for Control and Experiment Classes

Giving motivation questionnaires to control class and experimental class students is done to find out whether there is an effect of using textbooks that use QR-Code on student motivation. Motivation questionnaires were given to the control class and experimental class with 20 questions in the form of positive and negative questions. The results of the measurement of learning motivation are presented in table 2.

Table 2. The Mean of Students' Motivation

	N	Minimum	Maximum	Mean	Std. Deviation
Eksperimen	30	47	100	74.70	11.463
Control	30	34	50	38.43	4.232

Source: Research in 2024

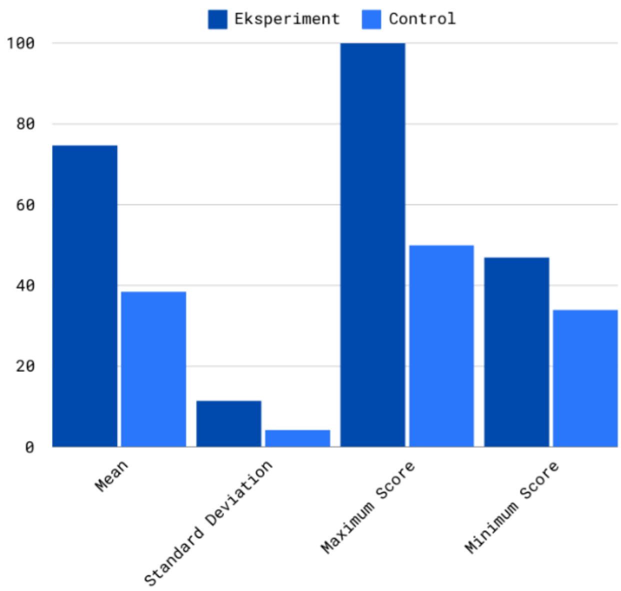

Figure 2. Diagram of Statistical Result of Students' Motivation

The table shows that for the control class that uses a textbook that is only text-based, has a mean of 38.43. As for the experimental class that uses a textbook with QR-code to access interesting learning content of 74.70, these results indicate that the mean (average) of the results of the statistical calculation of the motivation questionnaire of the experimental class is higher than the control class. The data for the average value (mean) listed in table 2 can be clarified in Figure 2 which is depicted in the form of a histogram graph.

Prerequisite Analysis Test

Before analyzing the data, prerequisite testing of data analysis must be carried out. One of the requirements that must be fulfilled in order to use parametric statistics is that the sample comes from a normal population, which is by using the normality test, and the data from the sample (population) in the control and experimental classes have the same variance (homogeneous). The analysis can be seen in table 3 and 4.

Table 3. Normality Test of Pre-Test and Post-Test

		KolmogrovSmirnov[a]			**Shapiro-Wilk**		
	Class	**Statistic**	**df**	**Sig.**	**Statistic**	**df**	**Sig.**
Students Learning Outcomes	Experiment Pre-Test	.104	30	.200*	.966	30	.447
	Experiment Post-Test	.134	30	.182	.959	30	.296
	Control Pre-Test	.085	30	.200*	.972	30	.605
	Control Post-Test	.072	30	.200*	.990	30	.993

*. This is a lower bound of the true significance

a. Lilliefors Significance Correction

Based on the table above, it can be concluded that the data are normally distributed because the sig value > 0,05. It can be seen from the sig value of Experiment Pre-Test 0.447 > 0.05, Experiment Post-Test 0.296 > 0.05, Control Pre-Test 0.605 > 0.05, Control Post-Test 0.993 > 0.05. Therefore, since the data is normally distributed, the t-test can be used on those samples.

Based on the table above if the sig value > 0.05, it means that the data variants are the same or homogeneous and if the sig value < 0.05, it means that the data variants are not the same or not homogeneous. In the homogeneity test table above, the sig value is 0.068, 0.064, 0.065, and 0.068, which means that the data comes from the same variant or the data is homogeneous because the sig values are > 0.05. Because the data is homogeneous and has been proven to be normally distributed, the t-test can be carried out.

Table 4. The Homogeneity Test

		Levene Statistic	**df1**	**df2.**	**Sig.**
Students Learning Outcomes	Based on Mean	2.437	3	116	.068
	Based on Median	2.484	3	116	.064
	Based on Median and with adjusted df	2.484	3	104.027	.065
	Based on trimmed mean	2.444	3	116	.068

Hypothesis Testing

To test the hypothesis, first, the requirements for hypothesis test analysis must be fulfilled. Because the requirements for hypothesis testing have been fulfilled, hypothesis testing can be done with the t-test. This test is used to decide whether the hypothesis is accepted or rejected. The hypothesis to be tested is:

H_0 is accepted if the tcount < ttable and H_a is rejected.

H_a is accepted if the tcount > ttable and H_0 is rejected.

Based on the researcher's objective, which is to examine the effect of using a textbook that uses QR-Code on student learning outcomes and motivation, researchers used the paired samples t-test to examine the effect of learning media on student learning outcomes. The results of the paired samples t-test analysis can be seen in the table below.

Based on the output table above, it is known that the significance value (2-tailed) is 0.000 < 0.05, then H0 is rejected and Ha is accepted. Therefore, it can be concluded that there is an average difference between the pre-test and post-test learning outcomes in the experimental class, which means that there is an effect of using Qr-Code on students' English textbook on students' learning outcomes.

Table 5. Paired Sample T-Test of Students' Learning Outcomes

		Paired Differences							
		Mean	Std. Deviation	Std. Error Mean	95% Confidence Interval of the Difference		t	df	Sig. (2-tailed)
					Lower	Upper			
Pair 1	Pre-Test Eksperimen–Post-Test Eksperimen	-14.100	4.901	.895	-15.930	-12.270	-15.756	29	.000
Pair 2	Pre-Test Control - PostTest Control	-4.433	7.394	1.350	-7.194	-1.672	-3.284	29	.003

Motivation questionnaire data analysis

The results of statistical tests on motivation questionnaires using parametric tests, the paired sample t-test for students' learning motivation, can be seen in the following table:

Table 6. Analysis Descriptive of Students' Motivation

	N	Minimum	Maximum	Mean	Std. Deviation
Pre-Test Eksperimen	30	25	40	33.57	4.166
Post-Test Eksperimen	30	75	100	82.07	5.663
Pre-Test Control	30	34	50	38.43	4.232
Post-Test Control	30	42	60	49.53	6.191

Based on the results of the data on descriptive analysis showed that the average value (mean) of student motivation in the experimental class had an average pre-test of 33.57 and had an average post-test of 82.07. While in the control class has an average pre-test of 38.43 and post-test of 49.53. This shows that on average, the effectiveness rating of English textbooks that use Qr-Code is better than text-based textbooks only.

The hypotheses on students' motivation that will be tested are:

H_0 is accepted if the tcount < ttable and H_a is rejected.

H_a is accepted if the tcount > ttable and H_0 is rejected.

Table 7. Paired Sample T-Test of Students' Motivation

		Paired Differences					t	df	Sig. (2-tailed)
		Mean	Std. Deviation	Std. Error Mean	95% Confidence Interval of the Difference				
					Lower	Upper			
Pair 1	Pre-Test Eksperimen– Post-Test Eksperimen	-48.500	7.833	1.430	-51.425	-45.575	-33.912	29	.000
Pair 2	Pre-Test Control - PostTest Control	-11.100	7.563	1.381	-13.924	-8.276	-8.039	29	.000

Based on the output table above, it is found that the sig. value (2-tailed) is 0.000 < 0.05, which means that H0 is rejected and Ha is accepted. Therefore, it can be concluded that there is an effect of using Qr-Code on students' English textbook on students' motivation.

Discussion

The Effect of English Textbook using Qr-code on the Learning Outcomes

Based on the data analysis and hypothesis testing regarding the effect of English textbook using qr-code on the learning outcomes of grade 3rd students at Almaarif 02 Singosari Islamic Elementary School, the research results show that there is an effect of English textbook using qr-code on student learning outcomes because the sig. value from the results of data analysis shows the value of tcount> ttable (15.756 > 2.045) and sig. value = 0.000

which means the sig. value <0.05, then H0 is rejected.

Therefore, based on the t-test at the 95% level that has been carried out on two groups of samples, each group consisting of 30 samples, it can be concluded that English textbooks that use qr-code as learning media have a better effect on student learning outcomes significantly with an average (mean) of 74.7, when compared to the learning using text-based English textbooks with an average of only 38.43.

The significance of this result lies in the fact that it demonstrates the effectiveness of incorporating QR codes into English textbooks in enhancing students' learning outcomes. The use of QR codes in educational settings can be particularly beneficial for students who are more engaged and motivated by interactive and multimedia-rich learning materials. This study's findings support the idea that QR codes can be a valuable tool in enhancing student engagement and motivation, ultimately leading to improved learning outcomes.

The study's methodology, which involved comparing the performance of students in an experimental class using QR-code enriched textbooks with that of students in a control class using traditional textbooks without QR codes, provides a robust basis for the conclusions drawn. The use of a T-test to analyze the data ensures that the results are statistically significant and reliable.

The benefits of using QR codes in English textbooks are multifaceted. They provide an interactive and engaging learning experience for students, which can lead to increased motivation and participation in class activities. QR codes also offer a convenient way for students to access multimedia resources and interactive exercises, making learning more enjoyable and effective. Additionally, the use of QR codes can help teachers to assess students' progress and adjust their teaching methods accordingly, further enhancing the learning experience.

The use of QR codes in educational materials, including textbooks, can enhance learning outcomes by providing students with additional resources and interactive learning experiences. QR codes can link to videos, audio clips, or interactive simulations that supplement the textbook content, making learning more engaging and interactive. This can lead to improved retention and understanding of the material, as students are more likely to be actively involved in the learning process.

In addition, according to Sholihah (2023) QR codes can facilitate the use of multimedia resources in the classroom, which are known to be effective in enhancing learning outcomes. The use of multimedia resources can help students to better understand complex concepts and retain information more effectively, as they are more likely to be engaged and motivated by the interactive nature of multimedia content.

In summary, the incorporation of QR codes in English textbooks has been found to have a positive impact on students' learning outcomes.

The Effect of English Textbook using Qr-code on the Students' Motivation

Based on data analysis and hypothesis testing regarding the effect of Qr-Code in English textbook on students' learning motivation of 3rd grade students at Almaarif 02 Singosari Islamic Elementary School, the research results obtained through the paired sample t-test show that there is a difference between the mean values of the control and experimental classes. In the control class that used a text-based English textbook only had a mean (average) value in the pre-test of 38.43 and post-test of 49.53, while in the experimental class that used Englihs textbook that used qr-code had a mean (average) pre-test of 33.57 and post-test of 49.53. This shows that on average, there is an improvement in the average motivation of students in learning using Qr-Code in English textbook.

In addition to looking at the mean value of the two classes, the test is further strengthened by looking at the acquisition of the t value of 33.912 with a sig. value of 0.000. Because the sig. value < 0.05, H0 is rejected, which means that there is an effect of using QR-codes in English textbooks on students' learning motivation.

The experimental class that used qr-codes on English textbooks in the learning process had higher motivation than the control class that used text-based textbooks only. This is because students in the experimental class will be connected easily, quickly and practically to interesting animated learning videos, audio and games. Thus, students can enjoy every learning process. When students enjoy and engage in learning, they will be more motivated to learn English. High motivation in learning English can affect student learning outcomes.

Juliyanti (2021) stated that motivation is one of the important factors that affect students' learning and learning outcomes. A student who has motivation will be more active and the frequency of study will increase, which largely improves their learning outcomes. Mazidatun (2019) stated that the use of QR-codes in the learning process can increase students’ learning motivation thus increasing student attention to learning materials. Candra *et al* (2020) added that the use of QR-codes can also optimize the exploration of learning to students not only while in the classroom, but also outside the classroom.

The high students' learning motivation can also be seen from the persistence of students' learning according to Gusto (2015) that persistence in learning is needed by students to achieve a good learning achievement. Students who have persistence in learning will try to focus on participating in teaching and learning activities. Students who have a high level of motivation are not easily discouraged in facing learning difficulties. Interest in learning can also be said to be a driving force within the child that can lead to learning activities, which ensure continuity and give direction to learning activities. Thus, students will be diligent and persistent in learning because of their high interest in always reading and the learning outcomes will be achieved.

The benefits of using QR codes in English textbooks are multifaceted. They provide an interactive and engaging learning experience for students, which can lead to increased motivation and participation in class activities. QR codes also offer a convenient way for students to access multimedia resources and interactive exercises, making learning more enjoyable and effective. Additionally, the use of QR codes can help teachers to assess students' progress and adjust their teaching methods accordingly, further enhancing the learning experience.

In summary, the incorporation of QR codes into English textbooks has been found to have a positive impact on students' motivation in learning the language. The studies discussed above demonstrate the effectiveness of QR codes in enhancing student engagement, motivation, and learning outcomes, making them a valuable tool in modern English language education.

Conclusion

Based on the theoretical study and supported by the research results and referring to the problem formulation described in the previous chapter, it can be concluded that there is an effect of using Qr-Code on English textbooks on the learning outcomes of grade 3 students at Almaarif 02 Singosari Islamic Elementary School. This is evidenced by the results of hypothesis testing with a value (tcount > ttable (15.756 > 2.045) and obtained a sig value of 0.000 < 0.05). Thus, H0 is rejected and Ha is accepted. In addition, the use of Qr-Code in English textbooks also has a positive effect on student learning motivation. This can be seen from the Sig. value of 0.000, because sig. < 0.05 then H0 is rejected and Ha is accepted. meaning that the use of Qr-Code in English textbooks has an impact on student motivation towards the learning process.

Recommendations

Drawing on the the findings of this research, several recommendations can be made to support EFL students and teacher to support an effective and interactive learning process. In addition, to encourage student motivation in learning English so that it can improve student learning outcomes. Efl teachers should be provided with adequate training and resources on how to incorporate technology especially the use of Qr-Codes into their teaching practices. Regular evaluation of the effecetiveness of Qr-Code should be conducted to assess its impact. The teacher should be customized and personalized the content of Qr-Code to cater to the diverse learning needs and preferences of the students. Continuously gather feedback from students, teachers, and policymakers to make improvements and adjustments to the Qr-Code integration approach. This includes addressing any technical issues, updating content regulary, and incorporating innovative ideas for enhancing learning experiences. By implementing these recommendations, teachers can maximize the effectiveness of using QR codes in elementary school English textbooks, leading to improved learning outcomes and increased motivation among students.

Notes

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Chapter 3 - Digital Teaching Material and Media Integrating Local Potential in Biology for Biotechnology Learning: ASystematic Literature Review

Hefni Dwika Sari , Widi Purwianingsih , Siti Sriyati

Chapter Highlights

- 21st century education demands a need for contextualized teaching materials in learning. Currently, learning materials tend to focus on handbooks and do not consider local potential and students' daily lives. The Indonesian curriculum emphasizes the use of local potential, but its implementation is still limited. Digital learning modules, specifically e-modules, are proposed as a solution to integrate local potential in biotechnology learning. The local potential that can be raised includes traditional food processing according to the specialization of fermented food in each region.
- This research aims to review literature on e-modules that can help students understand the basic concepts of conventional biotechnology so that it can be a foundation in understanding Biotechnology material thoroughly, improve concept understanding and motivation, and provide meaningful experiences through local potential.
- The results show that it is important to understand and preserve local wisdom and integrate it in learning activities to provide a meaningful learning experience that creates motivation and can improve understanding. This effort must be done through the presentation of learning materials and learning approaches that are interesting, relevant, and practical.

Introduction

21st century education requires individuals to acquire information and technology management skills, develop the ability to learn and innovate, pursue careers, and meet the demands of the global market, while demonstrating good character. To effectively respond the high market demand for science and technology-based products, the education system needs to have components that are responsive to these challenges. One of the critical aspects of this education system is teaching materials. According to Haka (2020), learning materials have an important role in guiding learning activities. However, practice in the field shows that teachers often focus on conventional handbooks and textbooks from year to year. This phenomenon can have a negative impact on the development of students' knowledge, as textbooks tend to present generalised material that is less relevant to the context of students' daily lives. the context of students' daily lives.

The use of educational technology must also be adapted to the educational needs of a country, such as Indonesia, especially regarding the required content needed in the curriculum. Indonesian curriculum requirements for learning should utilize local potential (Marianingsih et al, 2021). The Indonesian independent curriculum has the main characteristics of learning to develop soft skills and student characteristics that focus on 7 themes, including the integration of local potential into learning (Kemdikbudristek, 2022). Integrating learning with local potential can encourage students to improve concept understanding and provide meaningful experiences (Caki et al., 2019; Wilujeng et al., 2023).

In order to introduce and maintain local potential in the context of learning, the strategy that can be applied is to integrate these values into learning materials through teaching materials.The findings of Wilujeng et al. (2020) noted that local natural potential, especially in biology learning modules in the school environment, is still not optimally utilized. One aspect of local potential that can be empowered is traditional food processing. For some people, traditional food is not only part of local wealth, but also a source of pride in the origin of the area where they were born and have blood ties.

The problems of learning biotechnology are closely related to the teaching materials used at the time learning (Utomo et al., 2020). One material that is quite difficult to teach is biotechnology material,Because biotechnology is descriptive and abstract, biotechnology material is needed mastery and correct basic concepts. Basic concepts that students do not understand making biotechnology material difficult to understand. Another factor is the lack of teaching materials contextual and difficult to understand, the allocation of learning time and the teacher's skills in explaining appropriately (Goh & Sze, 2019; Nordqvist & Aronsson, 2019; Zulpadly et al., 2016).

Previous research related to local potential in learning was researched by Wilujeng et al. (2020) results show that integrating learning with local potential can be encouraging students to increase understanding of concepts and provide meaningful experiences. Ivana's findings et al. (2021) noted that there is local potential, especially in environmental biology learning modules schools, are still not utilized optimally. Research by Haka et al. (2020), using e-modules based on local potential for ecosystem materials, can provide insight into local wisdom that can foster an attitude of caring for the environment and increase mastery of concepts, availability of practicum activities in the module and the existence of examples of ecosystems in the environment around students can make it easier for students in deepening the concept of material. Another similar study by Wilujeng et al. (2020) Video use local potential science learning in science material, the concept of learning energy is able to help students understand learning content because it is presented through visuals and sound in accordance with pedagogical benefits for teaching.

Previous research discussed the implementation of local potential in relation to underutilization e-modules have local potential in learning, then it is discussed that the use of teaching materials in the form of e-modules really fosters an attitude of caring for the environment and increases mastery of concepts and learning videos It also has the potential to visualize teaching content thereby generating learning motivation. Article This will discuss the context of local potential learning with a different theme, namely biotechnology conventionally sees the importance of this local potential to be studied considering that Biotechnology material has a purpose encourage students to gain a proper understanding of concepts, which has the potential to give rise to creative ideas scientific knowledge that can be applied in everyday life (Paš et al., 2019). Hence the necessity explored how local potential can be integrated into other materials, will then be discussed How can a combination of e-modules inserted with learning videos and animations become teaching materials interesting digital.

One of the teaching materials to train students' independence is a module. Modules are arranged systematically which includes content, methods and evaluation tools developed (Basilotta Gómez-Pablos et al., 2017). Integration of local potential can help students fully understand concepts and increase motivation learning (Laamena & Laurens, 2021). So this literature review research aims to find out more further related to learning containing local potential as well as digital teaching materials in the form of e-modules for conventional biotechnology materials. It is hoped that this module can help mastery of basic concepts correctly to understand biotechnology as a whole and advanced (modern) biotechnology. Study It is also hoped that this literature can become a further review for related research development of e-modules containing local potential in addition to mastering concepts in biotechnology material Conventional learning can also foster motivation in learning because of the lessons learned from it The environment around students will provide meaningful experiences.

Method

This article was prepared using a literature review method, which consists of: four stages of literature review. The initial stage includes topic selection, followed by search and selection articles that are relevant to previously determined topics. The next step involves analysis and literature synthesis, which is then followed by the final stage, namely collecting literature data for compiled into writing. In this study, a perspective approach or literature study method is used content analysis in accordance with the conceptual framework proposed by (P., 2020) that the stages Literature studies go through at least the stages of article collection, article reduction, analysis and synthesis of results findings and compiler of articles. The purpose of this literature review is to provide an overview to the reader regarding the sources that have been accessed during the preparation of a topic, as well as explaining the role of these sources in the context of preparing this article.

The focus of the discussion in this article is centered on research results related to keywords related to digital teaching materials, local potential, motivation and understanding of biotechnology concepts and materials conventional. The process of searching and selecting journals is carried out through platforms such as Google Scholar, Research Gate, Science Direct, Elsevier, Scopus and direct references to Education journals Biology which has international accreditation, as well as a national journal indexed by Sinta. Journals that selected are then investigated and synthesized, and the results and discussion of the research become the basis reflections which will later be used as a basis for further research. The main articles analyzed in this study have several inclusion criteria which can be seen in Table 1 and for mapping of research data distribution for the study focus can be seen in Table 2.

Table 1. Main Article Inclusion Criteria

No	Aspect	Inclusion
1.	Article Type	*Research Artikel*
2.	Publication Year	2018-2023
3.	Origin of the Article	International
4.	Scopus	Scopus Indexed
5.	Samples in Articles	Junior and Senior High School, Student of University
6.	Scope of Material Content	Biology and Science
7.	Number of Articles	36 Articles

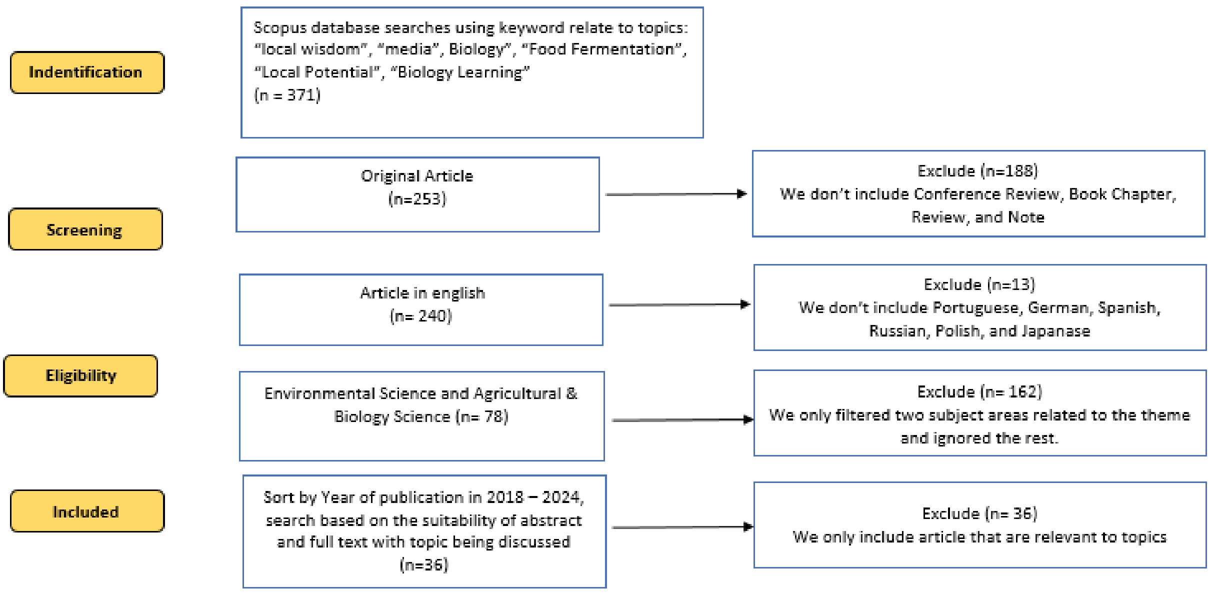

Figure 1. Prisma Flow Diagram For SLR

Table 2. Research Data Distribution Mapping

No	Study Focus	Authors	Number of Articles
1.	Local Potential and Educational Curriculum	(Goff et al., 2018; Haka et al., 2020; Hewitt et al., 2019; Paš et al., 2019; Wilujeng et al., 2020; Yoshiyama et al., 2019)	6 Articles

2.	Biotechnology Context, Problems and The Way How to teach	(Basilotta Gómez-Pablos et al., 2017; Goh & Sze, 2019; Ivana et al., 2021; Kiryak & Çalik, 2018; Kooffreh et al., 2021; Lyles & Oli, 2020; Materia et al., 2021; Nordqvist & Aronsson, 2019; Orhan & Sahin, 2018; Paš et al., 2019; Sumarni & Kadarwati, 2020; Uțoiu et al., 2018; Utomo et al., 2020; Wicaksono et al., 2020; Yoshiyama et al., 2019; Zulpadly et al., 2016)	13 Articles
3.	Development of Technology and E-module Teaching Materials	(Eilam & Gilbert, 2014; Fan et al., 2018; Goff et al., 2018; Gross et al., 2015; Haka et al., 2020; Utomo et al., 2020; Wilujeng et al., 2020)	7 Articles
4.	Implications and Assessment of Concept Understanding	(Cary et al., 2019; Fan et al., 2018; Goff et al., 2018; Laamena & Laurens, 2021; Marianingsih et al., 2021; Utomo et al., 2020; Wilujeng et al., 2020)	7 Articles
5.	Motivational Implications and Assessment	(Baierl et al., 2021; Olimpo et al., 2016; Soltani & Askarizadeh, 2021)	3 Articles

Results

Local Potential and Educational Curriculum

From a global perspective, improving natural science teaching can be obtained by providing opportunities for students to experience directly through activities that involve them with the environment and local potential around them (Yoshiyama et al., 2019). This approach is in line with science learning principles which emphasize the importance of activities and practices to facilitate students' understanding of the physical world (Wilujeng et al., 2020). This principle also covers the context of education in Indonesia, as regulated in Law of the Republic of Indonesia Number 20 of 2003 concerning the National Education System Chapter educational unit, regional potential, and student needs. Therefore, in the learning process, it is important to integrate activities that can connect students with the reality around them.

Education aims to shape humans so they can continue to develop their abilities to face changes caused by advances in science and technology. To achieve this mission, the implementation of education requires several crucial components, including learning materials. Learning materials have an important role in providing direction regarding the learning activities that will be carried out. However, in reality, teachers' use of learning materials tends to focus on handbooks and textbooks that are used regularly every year. This situation has the potential to influence the development of students' knowledge. Furthermore, textbooks often contain general material that is less related to the context of students' daily lives, as found by Haka et al. (2020). Traditional biology education often focuses on memorizing facts and concepts without considering the social relevance of the subject matter in students' real-world contexts, as stated by (Hewitt et al., 2019).

If proper preparation is the key to increasing achievement and creating an enthusiastic atmosphere in the classroom, then it is crucial to bridge the gap between how students are introduced to content outside the classroom and how they interact with that content during the teaching and learning process by linking learning to the environment. real, that is, it can be realized in practical ways directly related to the object or bringing the environment into learning in the form of teaching materials (Goff et al., 2018).

However, the integration of local potential into learning is still limited, and the use of the real environment has not been widely implemented. In addition, the current situation has caused the dimming of local potential values and local wisdom that develop in society (Haka et al., 2020). Meanwhile, the values contained in local community wisdom should be the focus of learning, especially in the context of learning related to the natural environment, in line with the curriculum which emphasizes respect for cultural diversity as an aspect that is worth studying. This can create a sense of pride and encourage the application of these values in students' lives, especially in social interactions in society.

Efforts to introduce and maintain local wisdom can be carried out through approaches in the educational environment, especially through school institutions, with the aim of improving the quality of learning. Every educational institution has the opportunity to present learning that suits students' interests and talents, explore regional potential, pay attention to the cultural environment, accommodate economic conditions, and accommodate local needs by designing adapted competency standards and basic competencies. In this way, the learning process will be more meaningful. Teachers can develop learning materials that contain elements of local wisdom in interesting learning activities, with the hope of forming students' character, stimulating learning motivation, and providing meaningful learning experiences.

The relationship between conventional biotechnology learning content and resources can be in the form of culinary potential in each region. This culinary potential includes food processing using natural fermentation techniques. With teaching materials that include information about local culinary delights and the implementation of field practicum activities, it is hoped that students can gain a deeper understanding of the material, make the learning process more meaningful, and learn about the cultural heritage around them. As a method of delivering material, it is best for the learning process to utilize teaching materials or supporting materials, including e-modules. Using modules as teaching materials can significantly help teachers in conveying biology material to students, because the material in the modules can be adapted to students' needs, allowing them to learn independently. Below is the distribution of articles by publication year regarding Digital Teaching Materials and Media Containing Local Potential in Biology.

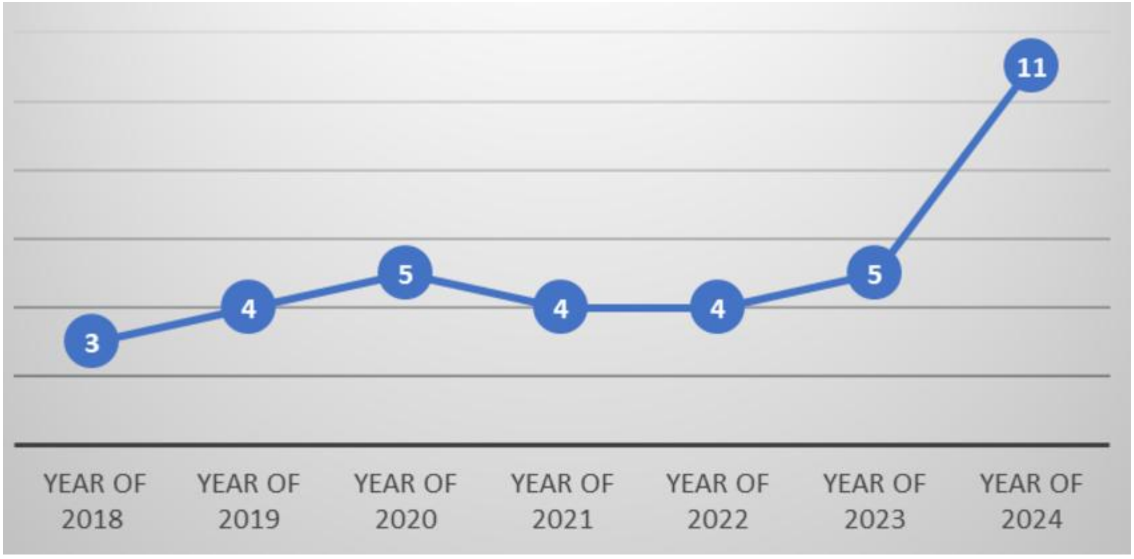

Figure 2. Distribution of Articles by Year of Publication

The chart titled 'Distribution of Articles by Year of Publication' presents the number of articles published between 2018 and 2024. There has been a noticeable increase in research on digital teaching materials and media containing local potential in biology over recent years. However, from 2018 to 2020, the number of publications remained relatively stable, with only a slight increase from 3 articles in 2018 to 4 articles in 2019 and 5 in 2020. It was in 2024 that the trend experienced a sharp rise, with 11 articles published, marking a significant surge. This surge in 2024 is likely due to the rapid advancement of technology, which has enhanced the development and accessibility of digital teaching resources. The growing interest in utilizing these resources in education can be attributed to the increasing integration of technology into teaching methods, which supports more interactive and effective learning experiences. This trend is consistent with broader educational shifts, where technology is increasingly viewed as a vital tool for improving the quality of learning and teaching strategies, especially in fields like biotechnology educationThis increase may be attributed to technological advancements that have made digital media and teaching materials more accessible and effective (Kumar et al., 2023). As these tools continue to evolve, there has likely been a growing interest in their application within education, driving further research and development in this field.

Biotechnology Context, Problems and The Way How to Teach

Biotechnology as a science is very complex, multidimensional, very scientific, technological, sociological and closely related to ethics because of its benefits which can improve human life standards and also experiences rapid development in the context of learning, which involves the systematic preparation of material including content, methods and evaluation tool so it is important to pay attention to aspects of science and technology, as well as how to apply them through the engineering/design process (Basilotta Gómez-Pablos et al., 2017; Utomo et al., 2020).

The field of biotechnology is also becoming increasingly influential on our society. With the increasing application of modern biotechnology, considerations regarding ethical and social issues arise, so it is important for the public to understand information that covers these aspects. Formal education at the high school level must play a role in helping students have sufficient understanding to become competent citizens in the field of biotechnology. Biotechnology has a significant role in rapid progress in various sectors of life. Although considered a complex scientific discipline, biotechnology involves aspects such as ethics, politics, and morals. As a highly complex and evolving field of science, biotechnology has a debated impact in various domains. Even though it is classified as a complex science, a deep understanding of biotechnology is crucial because of its close relationship with improving human welfare, as recognized by (Kooffreh et al., 2021).

The junior high school curriculum includes Biotechnology material with the aim of encouraging students to gain a proper understanding of concepts, which have the potential to give rise to creative scientific ideas that can be applied in everyday life. Education on biotechnology issues is expected to help students become 'biotechnology-literate citizens,' who have a deep understanding of modern biotechnology concepts and the basic principles of biotechnology. Education at the high school level, in particular, should provide students with sufficient biotechnological knowledge to shape their views about biotechnology and its implications, enabling them to make informed personal and social decisions (Paš et al., 2019). An adequate understanding of this field is needed by the younger generation in modern society so that they can face and overcome the ethical aspects that arise along with the development of modern biotechnology.

The development of science and technology makes Biotechnology material a field of natural science that students must master because this material is directly related to everyday life. This Biotechnology material continues to develop over time in line with the needs for 21st century skills which are characterized by increasing demands for creativity, perseverance and problem solving through group work. The complexity of Biotechnology material in learning requires proper mastery of basic concepts. Difficulties that are often encountered in learning Biotechnology are because students do not have an understanding of the basic concepts so that understanding the concept of biotechnology in its entirety becomes difficult. Basic concepts can be formed by building learning concepts that are close to the students' daily local environment (Goh & Sze, 2019; Nordqvist & Aronsson, 2019; Zulpadly et al., 2016).
The application of learning concepts using students' everyday local potential in the context of Biotechnology, especially in aspects of Conventional Biotechnology, was found from the following research:

Table 3. Context of Conventional Biotechnology in Learning in Several Countries

Authors dan Year of Publication	Country	Context of Conventional Biotechnology in Learning
Uțoiu et al. (2018)	Korea	The production of fermented "Kombucha" associated with honey bees in problem solving learning
Yoshiyama et al. (2019)	Japan	Making the traditional food "Natto", fermented soybeans using the bacteria *Bacillus natto* in problem solving learning
Ivana et al. (2021)	Indonesia	Making "Dadiah", buffalo milk fermented in bamboo tubes until thickened like yougurt is used as a learning resource
Lyles & Oli (2020)	America	Making various type of Kefir- *course based research experienced*
Materia et al. (2021)	Africa	Making traditional food "Mabisi, Akban, and Mahewu" learning about food nutrition

This learning approach can be adapted to the specificities of each region's fermented foods, allowing for local adjustments according to local food traditions. Involving students in practical work on making regional fermented foods, as shown in table 3. This can provide a meaningful dimension to the learning process, because students can be directly involved in processing foods that are generally consumed in their daily lives.

Biotechnology material contains abstract material that is difficult for students to understand. Print media may not be able to explain abstract processes but electronic media such as modules may be able to cover these shortcomings. Biotechnology learning problems are closely related to the teaching materials used during learning (Utomo et al., 2020). One of the teaching materials to train students' independence is a module. Therefore, it is very important to bridge barriers in student learning to form basic concepts related to biotechnology, namely conventional biotechnology, so that they can understand the material as a whole.

Some research has also combined the concept of learning local potential with STEM, such as projects making fermented foods such as tofu and grass jelly that are adapted from local community wisdom (example of research). Apart from that, it can also be applied to learning the Scientific Method material, where students can be involved in a project making natural detergent using typical regional plants, such as lerak (Sumarni & Kadarwati, 2020). It is worth noting that such projects can be adapted to the unique materials available in each region, allowing for local adaptations that enrich the student learning experience. Previous studies show that innovative teaching approaches, such as research-inquiry, problem solving, projects, argumentation, CKCM (Common Knowledge Construction Model) and web-based interdisciplinary learning, or a combination of the Biotechnology series learning (Biosel) model, a combination of GI and PBL learning models can increasing students' understanding and interest in science subjects, especially biotechnology (Goff et al., 2018; Haka et al., 2020; Kiryak & Çalik, 2018; Orhan & Sahin, 2018; Wicaksono et al., 2020).

Development of Technology and Teaching Materials

The importance of creating an education system that is responsive to the need for products based on high science and technology is crucial to meeting increasing market demands (Utomo et al., 2020). The impact of computer use and advances in information technology in the context of 21st century learning has significant relevance. Research indicates that the integration of educational technology in the classroom teaching process is positively correlated with student academic achievement. Findings from this research highlight the advantages of using integrated technology when compared to conventional teaching methods (Fan et al., 2018).

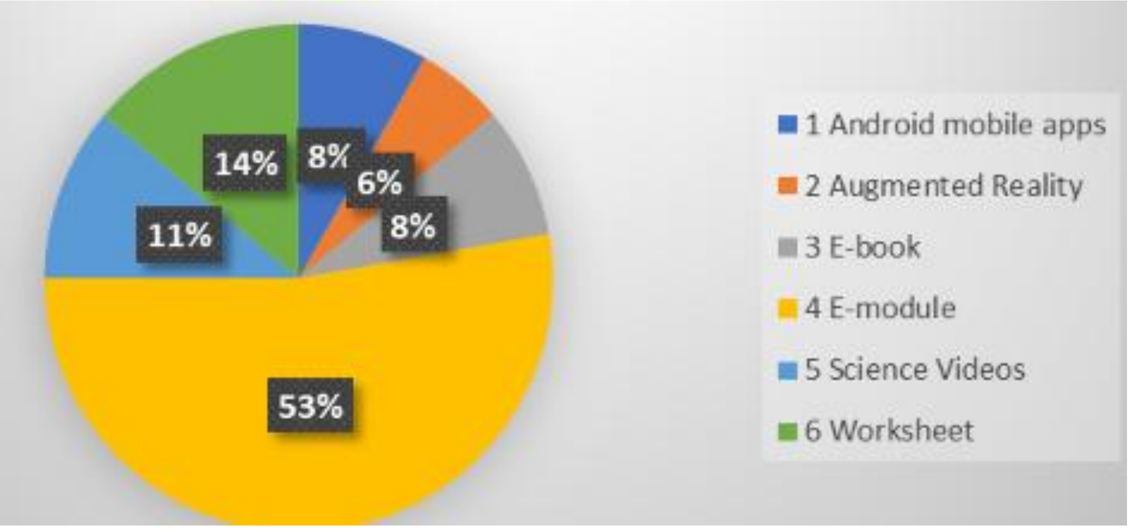

Figure 3. Classification of Digital Teaching Media and Material for local potential-based learning in Biology Learning

Teaching materials have the following practical values: First, they can overcome the constraints of students' limited experience. Second, teaching materials are able to overcome limitations in the classroom. Teaching materials, especially modules, are used to present learning material that is too complex for students to understand directly (Utomo et al., 2020). This is in line with the benefits of teaching media and materials, including their ability to (a) detail the delivery of messages or information so that they can improve student learning processes and outcomes; (b) enrich and captivate students' attention to increase learning motivation; (c) facilitate students' direct interaction with each other and their environment; (d) encourage students to learn independently according to their abilities and interests; (e) provide solutions to learning obstacles related to perception, space and time; and (f) provide equal experiences and opportunities for students to understand the world around them (Wilujeng et al., 2020).

The following is presented in Table 2 regarding various research and findings related to the pedagogical benefits of using technology and teaching materials in learning and Figure 3. Classification of Digital Teaching Media and Material for local potential-based learning in Biology Learning

Table 5. Variety of Research on the Use of Technology and Teaching Materials

Authors and Year of Publication	Technology Utilization and Teaching Materials	Results
Haka et al. (2020)	Utilization of local potential-based e-modules for ecosystem materials	The learning module provides insight into local wisdom which can foster an attitude of caring for the environment, the availability of practical activities in the module and examples of ecosystems in the environment around students makes it easier for students to deepen their understanding of the concepts of the material
Wilujeng et al. (2020)	Utilization local potential science learning videos in energy concept science materials	The use of learning videos is able to help students understand learning content because they are presented through visuals and sound in accordance with pedagogical benefits for teaching as well as increasing understanding, motivation and science process abilities
Utomo et al. (2020)	Utilization of STEAM biotechnology e-modules	The biotechnology module encourages students to understand the concepts of biotechnology material through discussions and supports visualization representations that stimulate learning motivation
Fan et al. (2018)	Utilization of animated videos for respiratory system material	The inclusion of technology into everyday classroom teaching can help students improve their visualization, improve conceptual understanding and academic achievement.
(Goff et al., 2018)	utilization of e-modules and animation of cell division material	Learning modules that provide learners with cognitive assistance, enabling them to process information more efficiently and resulting in the formation of more accurate mental models

Based on the data obtained regarding the classification of digital teaching media and materials *(Fig.3)*, e-modules are particularly popular for teaching biology that integrates local potential. Therefore, a further discussion will focus on the development of e-modules in this context. Developing teaching materials in the form of e-modules can include features in the form of animation and video. In current developments, animation is often included in online learning modules that can be implemented throughout undergraduate biology programs as an independent learning tool (Goff et al., 2018). Studies on the use of dynamic animated multimedia have emphasized students' ability to engage in independent learning outside the classroom. Students are given instructions about what will be shown and what key concepts must be understood from the animation. These instructions follow pretraining principles by providing guidance and introducing key ideas, which should reduce cognitive strain on learners as they work through the learning module segments, providing learners with cognitive assistance, allowing them to process information more efficiently and resulting in the formation of more accurate mental models (Fan et al., 2018).

Research by Fan et al. (2018) have shown that the inclusion of technology into everyday classroom teaching can help students improve their visualization, improve conceptual understanding and academic achievement. One increasingly popular alternative to textbooks and writing assignments is the use of online multimedia learning resources both inside and outside the classroom. Well-developed multimedia resources give teachers an option to allow students to process conceptual information in a short time (Goff et al., 2018).

The development of modules that insert videos turns out to have pedagogical benefits for teaching and learning that have been revealed by previous studies. Videos inserted in learning are able to help students understand learning material because they are presented through visuals and sound. Additionally, students can extend and increase their study time by watching videos again at home, so they can gather more information. With its audio-visual characteristics, videos enable students to understand new information quickly and easily. quickly and easily, encouraging students' imagination and thinking skills. Furthermore, videos are able to convey information through realistic representations. Therefore, students regardless of their intelligence level can learn from videos at the same time and demonstrate the desired response according to the learning objectives. In conclusion, learning via video is effective for increasing students' interest and helping them develop intrinsic motivation to learn (Goff et al., 2018)

Developing learning modules by paying attention to the cognitive load of the content presented can provide information to students in the right sub-concepts and learn at their own learning pace. E-module is a method of presenting independent learning material that is well structured in special learning units, presented in electronic format. Each learning activity in this e-module is connected via links as a navigation tool, which significantly increases the interactive level of students towards the program. This e-module is also equipped with video tutorials, animation and audio with the aim of enriching the learning experience, so that students are more intensely involved in the entire learning process (Kemendikbud, 2022).

To develop an effective learning module so that it can convey the biological concepts needed for biology students, during the design process. In accordance with the segmentation principle that must exist in learning multimedia including e-modules, the conceptual information presented by the learning module can be divided into three segments (Eilam &

Gilbert, 2014; Goff et al., 2018).

Table 6. Principles of E-Module Design Segmentation Development

Segment	Description
Segment 1	At the beginning of each segment, there are "thinking questions" to spark students. These questions provide further structure, focus students' attention on important ideas, and encourage higher-level thinking while watching the animation
Segment 2	After viewing an animated clip for a particular section, students are then asked to answer a number of follow-up questions about what they have seen. This is a follow-up question after the concept introduction period in order to further strengthen student learning and provide a means of formative assessment. Students are given immediate feedback on their answers and may be allowed (or not) to rewatch the animation before continuing if they feel the need to rewatch to understand the concept
Segment 3	To conclude the module which is the third part, students are given another group of summative questions which are intended to provide feedback on all the concepts in the module. The purpose of these summative questions aims to synthesize the concepts presented in each module segment and provide feedback to help correct student misconceptions.

Conclusion The results of the investigation showed that students using independent learning modules achieved much higher results than students who received instruction in traditional learning (lecture form only). By utilizing effective multimedia learning materials, teachers can provide effective instruction before class assignments to read modules first, thus allowing class time to be used for active learning activities rather than traditional lectures (Gross et al., 2015). The dynamic and interactive learning modules presented here provide students with cognitive assistance that can improve conceptual understanding. This, along with the ability to provide one-on-one interaction with the material, can assist this module in providing an effective alternative environment for students to reinforce ideas about the learning material.

Implications and Assessment of Concept Understanding

Increased mastery of deeper concepts can only be encouraged if students are enabled to actively participate in learning activities that require them to make direct observations of objects. This is confirmed by Goff et al. (2018) active student involvement in the learning process as a key factor in increasing students' conceptual understanding. Indeed, consistent application of active learning strategies has been shown to improve student achievement and concept retention in the classroom. So, as a result, this improvement is reflected in students' cognitive learning outcomes. students' cognitive learning outcomes. Apart from that, teaching and learning strategies can also influence students' mastery of concepts. Therefore, it is hoped that the integration of local potential and learning materials can appropriately and contextually help students understand concepts appropriately and contextually (Laamena & Laurens, 2021). Meaningful learning can improve student learning achievement in all aspects because students can understand the learning material well (Marianingsih et al., 2021). This needs to be taken into account because mastery of science concepts is still relatively low and increasing it is the collective responsibility of science education practitioners (Wilujeng et al., 2020).

Mastery of concepts, as a manifestation of cognitive ability, is a crucial aspect in evaluating the success of science learning. Success in the process of mastering science concepts can be measured by students' ability to simplify abstract material to make it easier to understand, provide interpretation, and the ability to apply it in everyday life situations (Kiryak & Çalik, 2018). To measure the level of concept mastery, it can be used various evaluation methods such as multiple choice tests and essays. Comparisons between pre-test and post-test scores can be made based on categories and human cognitive processes, which include aspects of memorizing, understanding, applying, analyzing, evaluating and creating. This measurement must be adjusted to the material and learning objectives that have been taught. In addition, evaluating students' conceptual abilities is not only limited to theoretical mastery, but also requires students to apply and relate core concepts in the field of biology (Cary et al., 2019; Suratno., 2023; Wilujeng et al., 2020).

Fan et al. (2018) noted in their research that conceptual knowledge is not only limited to knowing the definitions of concepts, but students must be able to see 'bridges' between concepts and explain the relationships between these concepts. This is because, often, the concepts taught in biology are interrelated. Therefore, in order for students to form high-quality cognitive structures from these concepts, it is very important for them to be able to see the transitions and relationships between two concepts. For this reason, teachers ask students to evaluate the relationship between one concept and other concepts. This phase will be beneficial for students in the formation of high-quality cognitive structures from what they have learned, and it is more likely that students will gain knowledge and remember the concepts for a longer period of time.

Motivational Implications and Assessment

Motivation is a construct to identify intention, persistence, and quality of attention regarding situational learning and tasks. This contributes to the amount of energy (e.g., applying strategies, focusing attention) that students expend in activities and overall learning. Developing motives and motivation to study science is individual and based on experience. Therefore, more and more outreach facilities aim to engage students in science in authentic learning environments (Baierl et al., 2021).

Motivation related to conceptual understanding is described as "an internal state that generates, directs, and maintains goal-oriented behavior and plays an important role in the process of students' conceptual change and learning strategies (Soltani & Askarizadeh, 2021). Therefore, it is suspected that students' motivational beliefs (e.g., learning goal orientation, task value, and self-efficacy) influence students' self-regulated learning. On the other hand, students' motivation may be influenced by their previous academic experiences and their interpretation of the learning context (i.e., conceptions of learning) that enables them to better use self-regulated learning strategies. This view originates from Banduras' 1977 social cognitive theory which states that students' past learning experiences are related to their motivational beliefs. In short, it is hypothesized that students' regulated activities in science depend on motivational beliefs and their conceptions about learning science (Soltani & Askarizadeh, 2021).

Science education in America often uses measurements of student attitudes and motivation through the Science Motivation Questionnaire II-Biology (BMQ; Glynn et al., 2011). The BMQ consists of 25 Likert-item questions regarding intrinsic and extrinsic factors related to student motivation in the biological sciences (e.g., career motivation and value motivation, self-efficacy, self-determination). Each item is rated on a scale ranging from zero to four points (corresponding to “strongly disagree” to “strongly agree”), and a total score is tabulated for each factor (Olimpo et al., 2016)

Conclusion and Recommendations

Local potential and educational curriculum are the main concerns in the context of improving learning. The focus is on providing opportunities for students to be involved in activities that involve the environment and local potential around them, in accordance with Biology learning standards. The importance of understanding and preserving local wisdom creates the need to integrate it in learning. This effort must be made through the presentation of learning materials and learning approaches that are interesting, relevant and practical. One of them is that this learning approach can be adapted to the specificities of fermented foods in each region, allowing for local adjustments in accordance with local food traditions for conventional biotechnology materials, thereby providing a meaningful dimension to the learning process, because students can be directly involved in the processing of foods that are generally consumed in everyday life. Providing effective education also requires the development of local potential-based e-modules that present information through animation, video and audio to increase student understanding of concepts and learning motivation and provide sustainable pedagogical benefits. Apart from requiring appropriate teaching media and materials, the learning model used must be considered, several innovative teaching approaches such as Ethnoscience-STEM, Research-inquiry, problem solving, projects, argumentation, and web-based interdisciplinary learning, or the Biotechnology series learning model (Biosel) which is The combination of GI and PBL learning models can increase students' understanding and interest in science subjects, especially biotechnology.

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Chapter 4 - Students' Functional Thinking in Mathematical Problem-Solving: With and Without Scaffolding

Luthfiana Tarida , Mega Teguh Budiarto , Agung Lukito

Chapter Highlights

- Students need functional thinking to solve certain mathematical problems. However, some of them have difficulty in functional thinking, including determining covariational and correspondence relationships. Scaffolding is one potential aid to overcome functional thinking difficulties.
- This research aims to explore students' functional thinking processes in solving mathematical problems with and without scaffolding. This research involved two of the 142 students from the Deck Officer Program in Indonesia as subjects, with the pseudonyms Farhan and Pandu. Both participants had relatively similar initial mathematical abilities. Data was collected by using two types of problem-solving tasks and interviews. Type 1 problem-solving tasks detect the subject's difficulties in functional thinking. Scaffolding was given when Farhan and Pandu completed type 2 assignments and continued with interviews.
- The results of data analysis show that scaffolding has a positive impact in determining covariational and correspondence relationships. The same scaffolding can impact the subject's functional thinking processes differently.
- Based on these findings, researchers recommend further research to investigate other backgrounds, such as self-efficacy, which cause different impacts when providing the same scaffolding. The findings of this research can be used to develop lecturers' professionalism and encourage students' functional thinking processes.

Introduction

Functional thinking occurs when individuals find a suitable representation system to represent the general relation between two (or more) different quantities (Blanton & Kaput, 2011; Smith, 2008; Stephens et al., 2017). Vollrath (1986) stated that functional thinking is a way of thinking about working with functions. It is also the process of constructing, describing, and reasoning about functions (Smith, 2008). Functional thinking is closely related to the concept of function (Blanton & Kaput, 2011; Smith, 2008). A function is a mathematical statement that describes how two (or more) quantities vary in relation to each other (Tanişli, 2013). Functions are a common materials in all levels of mathematics education and act as a guideline throughout the mathematics curriculum (Günster & Weigand, 2020). In other words, functions are crucial for every student to learn and understand, especially in supporting the functional thinking process.

The importance of function for students needs to be addressed. Students around the world experience difficulties in learning function, and it has been widely recognized as one of the most challenging topics (Arcavi et al., 2017; Britton & Henderson, 2009; Francis Chow, 2011; Kieran, 2004; Macgregor & Stacey, 1994; Pepkin, 2004; Ralston, 2018). This difficulty also occurs in Indonesia; students have difficulty understanding algebraic expressions, applying arithmetic operations in numerical and algebraic expressions, understanding the different meanings of the "equal to" sign, and understanding variables (Jupri et al., 2014; Yang & Sianturi, 2020).

Based on the results of preliminary research, students in this study, which came from a Deck Officer Program in Indonesia, also have difficulty understanding function, even though it is a material that must be learned according to the International Maritime Organization (IMO) Model Course 7.03 curriculum, for officers in charge of a navigational watch. The students study nautical science related to how to sail safely. The concept of function becomes a bridge to understanding other materials related to competence in navigation.

The preliminary study informs that problem-solving is necessary for supporting students' functional thinking processes. This is in line with Kieran (2004); Kriegler (2004); Pitta-Pantazi (2020) and Smith (2008) who state that problem-solving is a potential tool for individuals to engage in functional thinking processes. Therefore, this study utilized problem-solving tasks to explore students' functional thinking process. The preliminary study found that students who had difficulty solving problems also needed scaffolding. Students were able to solve problems after being given scaffolding.

Scaffolding is a process that enables students to solve problems, carry out tasks, or achieve goals with the help of more capable people (Wood et al., 1976). Gibbons (2002) defines scaffolding as temporary support that is intentional and responsive to help individuals move toward new skills, concepts, or levels of understanding. Scaffolding will be provided just in time, if needed and when individuals experience difficulties (Kim & Hannafin, 2011). This study defines scaffolding as assistance provided by others who are more capable in solving problems and optimizing students'.

The scaffolding framework utilized here was adapted from Anghileri's (2006) scaffolding levels, supplemented with van de Pol's (2010) scaffolding forms. However, only the second and third levels were used as the research was not intended to study about teaching. The second level aims for students to understand function. The means used in the second level include instruction, giving hints, explaining and modelling when students solve problems. The third level aims to enable students to perform a functional thinking process. The means used at this level include questioning and feeding back.

Problem-solving and scaffolding are interrelated in improving students' functional thinking processes. This is also supported by several studies who have analyzed the link between problem-solving and scaffolding (Abdu et al., 2015; Kim & Hannafin, 2011; Margulieux & Catrambone, 2021). In sum, this study aims to explore the impact of scaffolding on the functional thinking process of two deck officer program students in mathematical problem-solving based on aspects of (1) identifying problems; (2) representing data; (3) finding recursive patterns; (4) finding covariational relationships; (5) finding correspondence relationships and (6) evaluating generalization results.

Method

The study employed qualitative design with an exploratory approach (Miles et al., 2014). The exploratory approach was chosen to answer the research question that inquired how scaffolding impacts the functional thinking process of the students in mathematical problem-solving. The interaction between the concept of scaffolding and the functional thinking process in mathematical problem-solving was explored in-depth through an exploratory approach.

Participants

The study was applied for research permits to three universities in Indonesia, particularly in the provinces of Central Java, East Java, and Yogyakarta. Research permits for this study were received from the universities in Central Java and East Java provinces. The research began by collecting initial math ability data through the math ability test (MAT). 142 students were divided into five rooms, each with 20-30 students. They took a 90-minute math ability test together. On different days, they tackled a 90-minute PST1 and received scaffolding during a 120-minute PST2. They were chosen based on their equivalent abilities. Semi-structured interviews were conducted individually for 60 minutes to explore the impact of scaffolding on Farhan and Pandu's functional thinking process. The problem-solving process, scaffolding, and interviews were audiovisually recorded following the agreed research ethics. The entire research data collection procedure is summarized in Figure 1.

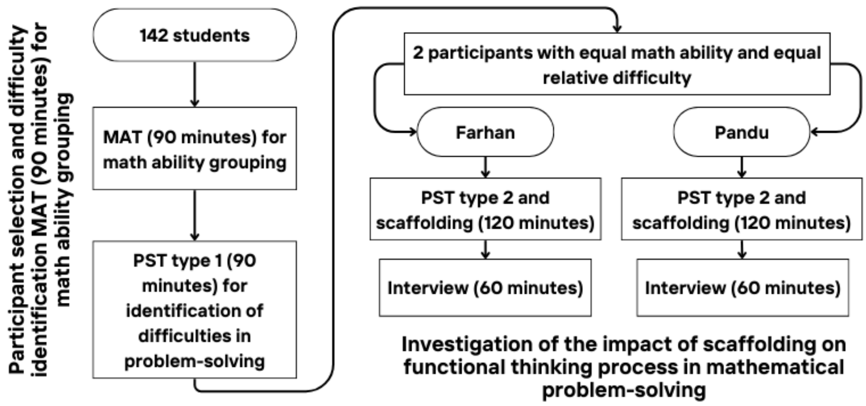

Figure 1. Data Collection Procedure

Strategies

The researchers of this study were the main instruments of this research who acted as planners, implementers, data collectors, and analyzers (Merriam, 1998). Additionally, the auxiliary instruments used in this study included a test of initial mathematics ability, two types of equivalent problem-solving tasks, and semi-structured interview guidelines. The initial math ability test and type 1 problem-solving task (hereinafter PST1; ship stopping distance) were utilized as guidelines for selecting participants to interview. The PST1 was also used to identify participants' difficulties in mathematical problem-solving that linked with functional thinking processes. In addition, problem-solving task type 2 (hereinafter PST2; ballast water discharge) was used alongside the scaffolding guidelines. A task-based semi-structured interview guide was used to explore the impact of scaffolding on students' functional thinking processes in mathematical problem-solving. The problem-solving tasks consisted of non-routine math problems with linear interpolation material, specifically "uses linear interpolation to find intermediate values in tables". PST was organized based on aspects and indicators of functional thinking (see Table 1). PST was validated by assessing the material, construction, language, and suitability with functional thinking indicators. Three math experts validated them, confirming their efficacy in triggering students' functional thinking with minor improvements.

Table 1. Indicators of Functional Thinking (FT)

Aspects of FT	Indicators of FT
Identifying the problem	• Recognizing changes in each quantity • Noticing the relationship between two quantities • Noticing some quantities are both independent and dependent variables
Representing data	Transforming data from tabular to graphical form
Finding recursive patterns	Finding changes in each variable value based on the graph
Finding covariational relationships	• Predicting the relationship between two variables based on a graph • Predicting an unknown value based on a graph
Finding correspondence relationships	Creating a general rule based on the graph
Evaluating generalization results	Testing the correctness of the general rule
Identifying the problem	• Recognizing changes in each quantity • Noticing the relationship between two quantities • Noticing some quantities are both independent and dependent variables
Representing data	Transforming data from tabular to graphical form

Data analysis

All data were analyzed using an interactive model, including data collection, display, condensation, conclusions, and drawing/verifying (Miles et al., 2014). Before condensing the data, the works of both selected participants on problem-solving tasks, scaffolding, and interview transcriptions were presented. The data condensation, explored in depth for conclusión, was carried out based on the data exposure. Exposure and condensation of data were adjusted to the indicators of functional thinking and scaffolding means. The coding of the data was organized according to the original order. The data obtained is the impact of scaffolding on both the participants' functional thinking process in solving mathematical problems. When drawing conclusions, the results were linked to and verified by research problems and objectives.

Checking the trustworthiness of research findings was done with four criteria: credibility, transferability, dependability, and confirmability (Lincoln & Guba, 1985). The credibility of qualitative research findings is checked using triangulation (Denzin & Lincoln, 2011). The triangulation was done through one method with two equivalent types: PST1 and PST2.

Results

The results and discussion in this study are divided into several sections: (1) identifying problems; (2) representing data; (3) finding recursive patterns; (4) finding covariational relationships; (5) finding correspondence relationships and (6) evaluating generalization rule.

Identifying Problems

First, the process of identifying problems was explored through interviews. **Farhan** began to identify problems by understanding the description of ballast water disposal in PST2. Farhan understood the changes in each quantity, namely changes in the time and water level data, and realized the relationship between time and water level. According to Farhan, the more time, the more the ballast water level decreases. Therefore, he realized that time is the independent variable while the water level is the dependent variable.

The second participant, **Pandu**, did not struggle to identify the problem, so the researcher did not provide scaffolding. Pandu identified the problem by understanding the description of the problem so that he could identify the information and objectives to be carried out. He identified information on the relationship between the time required during the ballast water disposal process and the ballast water level in the tank. He answered that the ballast water level would continue to decrease if the time duration continues to increase and realized that time was the independent variable while the water level is the dependent variable.

Representing Data

Question 1 on PST triggered the emergence of representing data in functional thinking. Data representation in the functional thinking process was broken down into indicators (tabular to graphic). **Farhan** answered question 1 (PST1) correctly, so difficulties were not identified in converting data from tabular to graphical form. Farhan solved question 1 by drawing a function graph based on the information in the table (see Figure 3). The x-axis signifies time, while the y-axis represents the water level. Farhan connected the points on the graph with a straight line, found patterns and relationships between two quantities in the table, and converted them into a graphical form. The two quantities were the ballast water level in the tank and the time required during the ballast water disposal process. Farhan's functional thinking process on representing data was carried out because he had understood the relationship between ballast water level and time. He stated that time affected the ballast water level, which was used as a counterweight, and loading and unloading processes occurred.

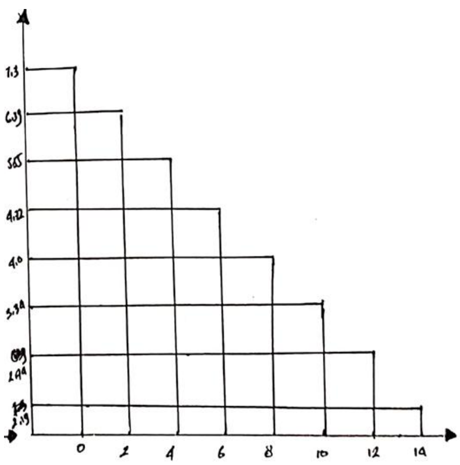

Figure 2. Farhan's answer on PST2 question 1

The representing data process of **Pandu** can be seen in Figure 4. Pandu represents water level on the x-axis and time on the y-axis, but does not pay attention to each pair of time and height (see Figure 4: red square). Therefore, scaffolding-instruction was provided by instructing Pandu to redraw the graph with paying attention to each pair of time and height according to the data in the table (see Figure 3: blue square).

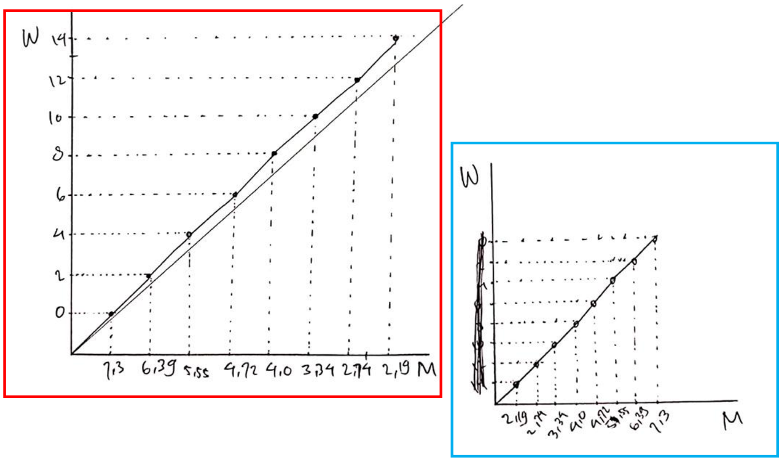

Figure 3. Pandu's answer on PST2 question 1

Finding Recursive Patterns, Covariational Relationships and Correspondence Relationships

Questions 2 and 3 triggered finding recursive patterns, determining covariational relationships, and finding correspondence relationships. In question 2(a), **Farhan** started by marking the point on the graph when the time was 13 seconds. Through scaffolding-explaining, the researchers provided information for Farhan to draw the graph separately so that Farhan wrote the answer as in Figure 4. Farhan estimated the water level at 13 seconds (among the known data) by finding a recursive pattern in the graph using similar triangles. This concept leads to linear interpolation.

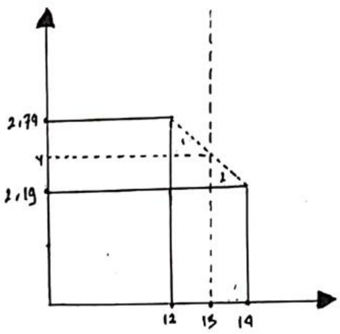

Figure 4. Farhan's answer on PST2 question 2(a) (graphic)

The researcher provided scaffolding-modeling using PST1 and gave an example of PST1 problem-solving in question 2(b). Farhan applied it to PST2. He assumed the relationship between the ballast water level and time using the concept of two congruent triangles (Method I) and linear interpolation (Method II) (see Figure 5). He stated that both methods have the same water level estimation results when the time is 13 seconds. He realized the similarity of the two similar triangles and then compared each base and height to estimate the water level at 13 seconds of $2{,}465\ m$. In this process, Farhan miscalculated the comparison, so the researcher provided scaffolding questions by asking how to get this result. He realized that the calculation had to be corrected.

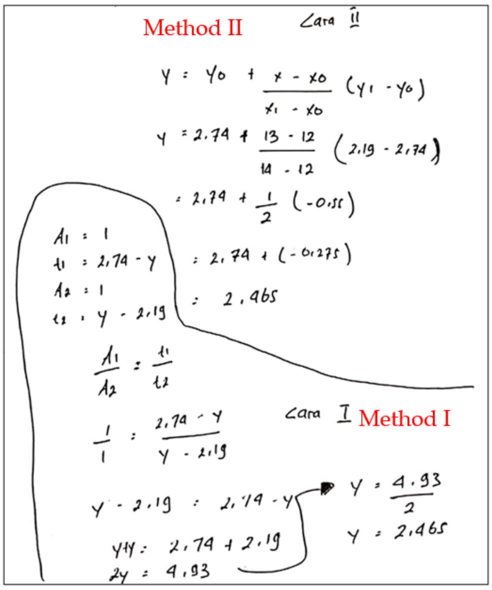

Figure 5. Farhan's answer on PST2 question 2(b)

The second participant, **Pandu**, found the covariational relationship between the two quantities in two ways/methods (same with Farhan). In Method I, Pandu used a simple comparison because 13 is the middle value of 12 and 14 (see Figure 6).

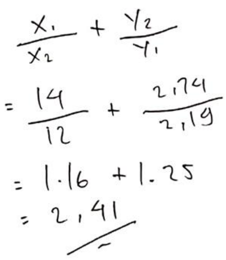

Figure 6. Pandu's answer on PST2 question 2(a) (method I)

In Method II, Pandu asked the researcher when estimate unknown values with the square rule of two congruent triangles, so the researcher gave scaffolding-questioning. The square pattern is the beginning of the discovery of the congruent triangle pattern (see Figure 7). Pandu compares two congruent triangles to obtain $x = 0{,}275$. The value of *x* is added to the water level of $2{,}19$ to obtain an estimate of the water level of $2{,}465$ at 13 seconds. He stated that method I and method II produced water level estimation results that were not much different at 13 seconds.

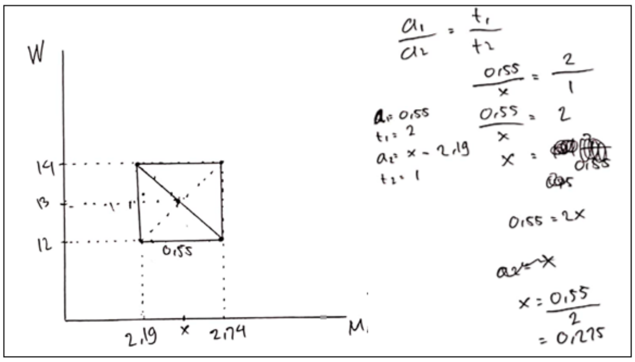

Figure 7. Pandu's answer on PST2 question 2(a) (method II)

Pandu found the general rule with scaffolding-modeling. The researcher gave an example of determining a variable symbol based on a certain quantity. In question 2(b), Pandu chooses method II as the most feasible way to estimate the value of unknown data because it can be used not only on data in the middle. The general rule found in method II leads to the concept of linear interpolation.

Evaluating Generalization Rule

Farhan generalized the relationship structure between time and ballast water level with linear interpolation. The concept of linear interpolation was discovered through a comparison of two congruent triangles. Farhan announced a general rule by estimating unknown data on the PST using congruent triangles/linear interpolation. Farhan estimate water level at 12 seconds. Estimated value $2{,}765$ closely matched known value $2{,}74$. This evaluation arose after the researcher gave scaffolding questions (“How is the estimation of the ballast water level at a known time? Are the estimation results the same as the information in the table?") to Farhan. These questions helped Farhan to generalise the relationship between ballast water level and time. Farhan evaluated the results of generalization by checking the use of these concepts in answering PST1. He also checked the use of concepts obtained from the known data values in the table. **Pandu** devised a general rule using linear interpolation and congruent triangles. He verified his method by checking known data. Given 4 seconds, the estimated and known ballast water levels matched at 5,55 meters. This evaluation followed the scaffolding questioning.

Functional Thinking Process in Mathematical Problem-Solving with Scaffolding

Scaffolding is closely related to the Zone of Proximal Development (ZPD). Vygotsky (1978) defines ZPD as the distance between the actual level of development determined by independent problem-solving and the potential level of development determined through problem-solving under adult guidance or in collaboration with more capable peers. The scaffolding used in this study is adapted from van de Pol et al (2010) scaffolding means. Scaffolding means that can support students' learning activities are: (1) feeding back: providing information related to student performance; (2) giving hints: providing hints or suggestions; (3) instruction: what to do or how something should be done and why; (4) explaining: providing more detailed information or clarification; (5) modelling: offering behaviour to be imitated; (6) questioning: questions that require linguistic and cognitively active answers.

Van de Pol's scaffolding means are further linked to Anghileri's (2006) scaffolding levels. Anghileri proposed a three-level hierarchy of scaffolding as support in learning, including environmental provisions as level 1, explaining, reviewing and restructuring as level 2, and developing conceptual thinking as level 3. At level one, teachers help students learn with the environment created in the classroom before interacting with students. At this most basic level, assistance can also be in the form of instructions or commands on the module to help learners solve problems. Level 2 involves interaction between the teacher and the learner with consideration of the mathematical material. Assistance at level 2 includes: (1) Explaining is the way to reach the ideas or concepts used in problem-solving; (2) Reviewing is the way to encourage learners to understand better and comprehend the problem to be solved; (3) Restructuring is the way to rebuild learners' existing knowledge to solve the problem. At level 3, learners are supported in making connections and developing various representation means. The interaction between the teacher and the learner can create opportunities to reveal the learner's understanding. So, at level 1, scaffolding means are used: feeding back and giving hints. At level 2, scaffolding means are used: instruction, explaining and questioning. At level 3, the scaffolding modelling mean is used.

The scaffolding process in this study was carried out based on the three critical components of scaffolding as van de Pol et al. (2010) postulated. The three components include contingency, fading, and transfer of responsibility. Before providing scaffolding, the researcher first suspected the participants' difficulties through PST type 1 answers. This suspected difficulty is a mean for contingency. Fading is the gradual withdrawal of support. The scaffolding means provided by the researchers to participants trigger participants' functional thinking process through problem-solving in PST type 2. The researchers gradually withdrew these means until participants could solve their problems. Transfer of responsibility was carried out by giving participants the responsibility for solving PST type 2 after being given scaffolding means according to their difficulty. Transfer of responsibility can form participants' independence in the functional thinking process. The results of the research data analysis also support this. The results of the data analysis inform that scaffolding can encourage the emergence of students' functional thinking processes. The impact of scaffolding on students' functional thinking process is summarized in Table 2.

Table 2. Functional Thinking Process in Mathematical Problem-Solving with Scaffolding

P	Difficulty	*Scaffolding Mean*	Impact on Functional Thinking Process
FARHAN	None	**Level 1:** Without Feeding back dan giving hint	**Identifying Problem:** • Recognizing changes in each quantity • Noticing the relationship between two quantities • Noticing some quantities are both independent and dependent variable
	None	**Level 2:** Without instruction	**Representing Data:** • Converting data from tabular to graphical form
	Did not see the triangle pattern on the graph	**Level 2:** Explaining	**Finding Recursive Patterns:** • Finding the change of each variable value based on the triangular shape of the graph
	Difficulty finding relationships between triangular patterns on the graph Difficulty accessing related prior knowledge	**Level 2:** Questioning	**Finding Covariational Relationships:** • Predicting the relationship between two variables from the concept of simple comparison to the concept of two congruent triangles • Predicting unknown values with the concept of two congruent triangles

	Difficulty representing quantities with certain variables, so cannot make general rules.	**Level 3:** Modelling	**Finding Correspondence Relationships:** • Creating a general rule based on the previous concept of two congruent triangles (linear interpolation).
		Level 3: Questioning	**Evaluating Generalization Results:** • Testing the correctness of the general rule by checking the known values in the table. • Correcting the general rule when there is an error in the test result.
PANDU	None	**Level 1:** Without feeding back dan giving hint	**Identifying Problem:** • Recognizing changes in each quantity • Noticing the relationship between two quantities • Noticing some quantities are both independent and dependent variable
	Lack of understanding of the suitability of the distance between the data on the graph so that the graph does not represent the data according to the table	**Level 2:** Instruction	**Representing Data:** • Convert data from tabular to graphical form
	Not seeing the triangle pattern on the graph	**Level 2:** Explaining	**Finding Recursive Patterns:** • Find the change of each variable value based on the triangular shape of the graph
	Difficulty finding the relationship between triangular patterns on the graph	**Level 2:** Questioning	**Finding Covariational Relationships:** • Predicting the relationship between two variables with mean difference, linear interpolation and the concept of square • Predicting unknown values with mean difference, linear interpolation and the concept of square (the beginning of the discovery of the congruent triangle pattern)
	Difficulty representing quantities with certain variables so that they cannot make general rules	**Level 3:** Modelling	**Finding Correspondence Relationships:** • Create a general rule based on the previous concept of two congruent triangles (linear interpolation).
		Level 3: Questioning	**Evaluating Generalization Rule:** • Testing the correctness of the general rule by checking the known values in the table. • Correcting the general rule when there is an error in the test result

Discussion

The discussion in this study are divided into several sections as follows, (1) students' functional thinking processes in mathematical problem-solving, and (2) the impact of scaffolding on students' functional thinking processes in mathematical problem-solving.

Functional Thinking Process in Mathematical Problem-Solving

Based on the research findings, Farhan and Pandu started the functional thinking process by identifying problems. The problem identification process was characterized by understanding the changes and relationships between two quantities and realizing which quantities are independent variables and dependent variables. Changes and relationships between two quantities are characteristic of the functional thinking process (Blanton & Kaput, 2011; Carpenter, 2005; Carraher, 2019; Pitta-Pantazi, 2020; Smith, 2008).

Representation is closely related to functional thinking, so representing Farhan and Pandu data triggers further aspects of functional thinking. This is supported by the research results by Blanton & Kaput (2011), which state that representation can help students build patterns. Smith's functional thinking framework (2008) also discusses the importance of representation in functional thinking, one of which is making notes according to quantity, usually in tables, graphs or icons.

Three characteristics of functional thinking are emphasized here. Recursive patterns involve variable value changes via congruent triangles, covariational relationships predict variable links, while correspondence relationships derive general rules from congruent triangles. These three characteristics by Kaput's (2008) reflect a situation where a person looks for ways to express variations from various examples by involving the idea of causality, growth, and continuous co-variation. Previous researchers also express functional thinking characteristics (Blanton & Kaput, 2011; Sibgatullin et al., 2022; Smith, 2008; Stephens et al., 2017).

The correspondence relationship is a generalization of the relation of two quantities. Checking the generalization results appears when researchers provide scaffolding-questioning to Farhan and Pandu. The aspect of evaluating generalization results is the development of Smith's (2008) functional thinking aspects associated with Schoenfeld's (1985) problem-solving stages. Schoenfeld's problem-solving stages include analysis, design, exploration, implementation and verification. Schoenfeld's problem-solving is chosen as a mean to explore the functional thinking process because it allows for cyclic flow.

The analysis stage begins with problem identification, extracting relevant information. In the design stage, students devise problem-solving strategies, including mathematical modeling.

Exploration involves trying various approaches, while implementation applies general rules. Verification checks temporary solutions against initial conditions, refining until a final solution is reached.

The Impact of Scaffolding on Students' Functional Thinking Process in Mathematical Problem Solving

Scaffolding is closely related to the Zone of Proximal Development (ZPD). Vygotsky (1978) defines ZPD as the distance between the actual level of development determined by independent problem-solving and the potential level of development determined through problem-solving under adult guidance or in collaboration with more capable peers. The scaffolding used in this study is adapted from van de Pol et al (2010) scaffolding means. Scaffolding means that can support students' learning activities are: (1) feeding back: providing information related to student performance; (2) giving hints: providing hints or suggestions; (3) instruction: what to do or how something should be done and why; (4) explaining: providing more detailed information or clarification; (5) modelling: offering behaviour to be imitated; (6) questioning: questions that require linguistic and cognitively active answers.

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The scaffolding process in this study was carried out based on the three critical components of scaffolding as van de Pol et al. (2010) postulated. The three components include contingency, fading, and transfer of responsibility. Before providing scaffolding, the researcher first suspected the participants' difficulties through PST type 1 answers. This suspected difficulty is a mean for contingency. Fading is the gradual withdrawal of support. The scaffolding means provided by the researchers to participants trigger participants' functional thinking process through problem-solving in PST type 2. The researchers gradually withdrew these means until participants could solve their problems. Transfer of responsibility was carried out by giving participants the responsibility for solving PST type 2 after being given scaffolding means according to their difficulty. Transfer of responsibility can form participants' independence in the functional thinking process.

Farhan and Pandu have relatively the same mathematical abilities, but there are differences in difficulty and scaffolding at level 2. Farhan drew a graph that correctly represented the data without scaffolding instruction, while Pandu needed scaffolding instruction to correctly represent the data on the graph. In addition, there are differences in the impact of providing the same scaffolding on the functional thinking process of Farhan and Pandu. The difference occurs in finding recursive patterns and finding covariational and correspondence relationships; Farhan could only use one way, while Pandu used more than one way. This is likely related to Farhan's belief in his ability to complete specific tasks. Such beliefs lead to self-efficacy, first introduced by Bandura (1986). Therefore, further research is needed to explore the relationship between self-efficacy and students' functional thinking processes.

Conclusion

Overall, scaffolding positively impacts students' functional thinking processes in mathematical problem-solving. Farhan and Pandu have relatively similar initial mathematics and abilities but slightly different scaffolding impacts their functional thinking processes. Based on these findings, the researcher recommends further research to investigate the background that can cause different impacts on the provision of the same scaffolding means.

Recommendations

Participants have relatively the same mathematical abilities, but there are differences in difficulty and scaffolding. This is likely related to Farhan's belief in his ability to complete specific tasks. Such beliefs lead to self-efficacy, first introduced by Bandura (1986). Therefore, further research is needed to explore the relationship between self-efficacy and students' functional thinking processes.

Notes

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Chapter 5 - Lighting the Way: Scaling the Microgrid Project to Promote STEM Learning in Rural Non-Privileged Communities

Marcelo Caplan

Chapter Highlights

- The "Microgrid V2.0" project seeks to scale and refine an educational initiative promoting STEM skills in rural Latin American schools through a hybrid learning approach. Building on a successful pilot (Microgrid V1.0), this phase involves eleven schools, engaging students in hands-on projects focused on renewable energy.
- By implementing blended learning with remote and local instructors, the project aims to bridge educational disparities and foster community empowerment.
- Results indicate a significant increase in students' content knowledge, particularly among those actively participating in synchronous and asynchronous sessions. However, logistical challenges, such as connectivity issues and local instructor participation, impacted some schools' outcomes. Addressing these barriers through enhanced teacher training and improved support systems will be crucial for future iterations.
- The project exemplifies scalable STEM education, promoting sustainability and inspiring rural youth toward STEM careers.

Introduction

The growing need for sustainable energy in rural and underserved areas has sparked global interest in educational programs that address both the technical and social challenges of energy access. At the same time, rural schools face significant challenges compared to their urban counterparts, especially in access to quality STEM education. To help close this gap, a hybrid learning model was developed to promote topics like Energy, Electricity, and Sustainability in rural and urban communities. To test this model's tools and feasibility, a pilot project called Microgrid V1.0 was launched in four Latin American schools. The goal was to provide students and teachers in underprivileged rural schools with the skills to design and build renewable energy systems, specifically microgrids. The project combined hands-on learning with remote instruction, offering a blended approach that integrated key STEM concepts such as energy transformation, sustainability, and electricity generation.

In the first phase, detailed in the initial paper (Caplan, 2024), the project demonstrated that students from rural areas, often lacking access to advanced technological resources and specialized teachers, could successfully construct functional microgrid systems within their schools, and at the same time, to acquire the academic knowledge needed. This pilot provided valuable insights into the potential for such programs to foster both academic learning and community empowerment by involving students directly in solving local energy issues. The successful implementation across the four schools revealed not only the educational benefits but also the social impact of students becoming key contributors to their communities' access to electricity through renewable energy.

Building on the lessons learned from the pilot, this second phase expands the Microgrid project to twelve schools, broadening its geographical scope and deepening its impact. The goal of this second phase is twofold: 1) to scale the project and 2) to refine the instructional methodology based on the feedback and challenges encountered during the pilot. In this paper, we will explore the implementation process in these twelve schools, focusing on the logistical adjustments made to accommodate the larger number of participants and the diverse conditions across different regions. The project's educational framework continues to leverage remote instructors who collaborate with local teachers, ensuring that students in even the most isolated regions can access high-quality STEM education.

This phase also introduces new educational tools and resources, including enhanced use of digital platforms, asynchronous assignments, and expanded hands-on activities. By doing so, the project aims to not only improve students' understanding of renewable energy technologies but also to foster an interest in STEM careers among youth in remote areas. The expansion to twelve schools offers an opportunity to evaluate the scalability of the Microgrid project, with the intention of developing a replicable model that can be applied in other regions facing similar educational and energy challenges.

The paper will begin by providing a brief overview of the outcomes from the first phase of the project and the key lessons learned. It will then describe the strategies and modifications employed to scale the project, followed by an in-depth analysis of the educational and technical outcomes from the twelve participating schools. Finally, the challenges of scaling such an initiative and the implications for future STEM education programs in rural areas will be discussed.

Summary of the Implementation of Microgrid V1.0

The project "Remote Learning: A Means to Advance Educational Equity in Isolated or Rural Regions" explores an innovative approach to addressing the educational disparities between urban and rural regions, particularly in Latin America. The initiative seeks to tackle the educational challenges faced by rural schools, which often lack access to qualified teachers and educational resources, by using remote learning as a tool to bridge the gap. This pilot project involves the development of a blended learning model combining synchronous remote teaching with asynchronous local support, focusing on topics such as energy, electricity and sustainability.

Key Problem

Rural regions face significant educational inequities compared to their urban counterparts. Rural students, particularly at the high school level, are more likely to drop out due to a lack of subject-specific teachers and limited access to resources. While urban schools enjoy better infrastructure, rural schools are left with fewer qualified instructors and limited exposure to technology. The goal of the project is to ensure that students in these areas can have access to quality education on STEM subjects, preparing them for future careers and providing their communities with practical benefits.

Project Objectives

The primary aim of the pilot project is to equip rural students and their teachers with knowledge and practical skills in electricity and renewable energy. Students are expected to learn about energy, electricity and sustainability, and by the end of the course, construct a microgrid to ensure their school has a stable supply of electrical energy. The project also has a larger goal of encouraging students in rural areas to pursue STEM careers, providing them with both theoretical knowledge and hands-on experience.

Methodology

The project is based on a blended learning model, where urban teachers, referred to as "remote instructor," deliver lessons through video conferencing to students in rural areas, supported by local teachers who facilitate classroom logistics and assist with the learning process. This method allows students to access quality education remotely while still benefiting from the in-person support of a local instructor.

The learning process consists of eight synchronous weekly sessions led by remote instructor, supported by asynchronous activities managed by local teachers. The final two sessions focus on hands-on projects, such as building a solar charger for mobile phones and designing a model microgrid that can power a classroom.

Curriculum Design

The course, structured around the principles of project-based learning (PBL) with a strong STEM focus, covers topics such as:

1. **Energy and Electricity**: Students explore renewable and non-renewable energy sources, basic electrical concepts like voltage and current, and practical applications of electricity.
2. **Solar Energy and Photovoltaic Cells**: Students learn how solar panels work, their parameters, and how to convert solar energy into electricity.

3. **Microgrid Development**: Participants build a functional microgrid, gaining practical experience in energy storage, the conversion of direct current (DC) to alternating current (AC), and the use of inverters.

The course emphasizes hands-on learning through practical projects and demonstrations, such as constructing solar chargers and model microgrids. Students engage with real-world challenges, developing creative solutions and working collaboratively to apply theoretical concepts to practical tasks.

Evaluation

The project includes several evaluation mechanisms to measure both the academic outcomes and students' attitudes toward STEM careers. Students take pre- and post-tests to assess their knowledge gain in topics related to solar energy and electricity. Additionally, a STEM attitude survey gauges any changes in students' perceptions of STEM fields and their interest in pursuing careers in these areas and a myriad of formative assessments and questionnaires to improve the development of the educational model for futures implementations.

Key Findings

The results from the pilot project implemented in four schools in Latin America (two in Argentina, one in Colombia and one in Mexico) indicate that the blended learning model significantly improves students' content knowledge. The use of both remote and local instructors helps bridge the gap in educational resources, providing rural students with a richer learning experience. The hands-on projects have proven to be highly engaging, with students demonstrating an understanding of the practical applications of the knowledge they acquire.

Challenges

Despite the project's successes, several challenges emerged during implementation. Connectivity issues in rural areas, weather conditions affecting school access, and logistical conflicts within the local schools occasionally disrupted synchronous sessions. Moreover, students were sometimes unfamiliar with technology, such as Learning Management Systems (LMS), which required additional support from local instructors.

Improvements for Future Implementation

Based on feedback from students and instructors, several improvements have been identified for the next iteration of the project, MicroGrid V 2.0:

1. **Enhanced Interaction**: More interactive sessions, with greater involvement from local instructors, are needed to maintain student engagement and ensure active participation during both synchronous and asynchronous activities.
2. **Pre-Project Training**: Local instructors should receive more extensive training on the course content and the use of LMS platforms before the start of the project to ensure smoother implementation.
3. **Increased Hands-On Learning**: Students have expressed a desire for more practical activities and real-world applications, so future versions of the course will include additional experiments and interactive tasks.
4. **Improved Connectivity Solutions**: As connectivity remains a significant obstacle, strategies to address internet limitations in rural areas must be prioritized, such as the use of offline resources or improved infrastructure.

The project has demonstrated that remote learning, combined with hands-on STEM education, can be a powerful tool for promoting educational equity in rural areas. The pilot program has shown that, with the right support, rural students can achieve a level of education comparable to their urban peers, particularly in areas like energy and sustainability. The project also highlights the potential of remote learning to not only fill the gap left by the shortage of qualified teachers in rural areas but also to foster a deeper interest in STEM careers among students in these communities.

Moving forward, the next phase of the project, Microgrid V 2.0, will build on the lessons learned from the pilot, incorporating feedback from participants to refine the curriculum and improve the overall learning experience. The goal is to create a scalable and replicable model that can be implemented in other rural communities, providing students across Latin America with greater access to quality education and the opportunity to engage with STEM fields in a meaningful way.

Following is the description of the development and implementation of the scale up project Microgrid V2.0

Implementation of the Project Microgrid V2.0

Following the feedback from the students and local instructors, before starting the process of identifying a set of new schools, the project implemented modifications in the LMS, in the evaluation tools, and in the preparation of the local instructors.

In this second version of the implementation of the project, the administration of the project procured to develop two important aspects to facilitate the scale up of the project: 1) a strategy to decentralize the logistics of the project and include more local institutions in the management of the daily activities of the project and 2) a program of professional development for the local instructors.

Strategy to Decentralize the Logistics of the Project.

In the version Microgrid V1.0, the author was running ALL the aspect of the project, from contacting and organizing the project in the different educational institutions, finding financial support for the materials needed for the project, dealing with the organization of the logistics of the project, and all the little details that are appearing during the implementation.

For the scale up of the project in the Microgrid V2.0, the first step is to find and include larger educational institutions, which ones have access to rural and non-privileged schools, that will take upon themselves the responsibility of the organization and follow up of the development of the project in their network of schools. In this implementation, four institutions assume this role: Universidad del Norte, in Barraquilla, Colombia, Computadoras para Educar , from the ministry of Education of Colombia, The Universidad Autonoma de San Luis de Potosi, Mexico, the Beneditina Universidad Autonoma de Puebla and and several independent school that decided to join the project.

The role of these large institutions is to be the administrative side of the program in their participating school, in this way the project needs to deal with a concentrate number of representatives instead with the multiple schools, in one hand, and in the other hand, these larger institutions will provide guidance to their schools and the resources needed for the implementation of the project. Following is the list of schools participating in the project Microgrid V2.0

Table 1. Participating Schools In The Project Microgrid V2.0

School Name	Organization	Country
Antonia Santos	Computadoras para Educar	Colombia
Jorge Arrieta	Computadoras para Educar	Colombia
IET Chivata	Computadoras para Educar	Colombia
Colegio Biffi	Universidad del Norte	Colombia
Colegio Real	Universidad del Norte	Colombia
Instituto La Salle	Universidad del Norte	Colombia
Santa Cruz CONAFE	Buap	Mexico
UASLP Huasteca Sur	UASLP	Mexico
Bachillerato Matlapa	UASLP	Mexico
Bachillerato Xlitla	UASLP	Mexico
IED Adolfo León Gómez	Independent	Colombia
Jerárquicos	Independent	Argentina
Sargento Cabral	Independent	Argentina
Liceo Lazaro	Independent	Rep Dominicana

Each organization had a coordinator that arranged the logistical issues with the rural school administrations, ensuring that the project had the needed institutional support from the local schools. The main points of these logistics arrangements was to ensure that the project was took seriously by the local school, integrating the curriculum of the project in the local curricula, ensuring that the local instructor will be dedicated to the project, and other administrative issues needed to solved before the program can run in a given school such as the classroom with the resources needed to the synchronous meetings, access to internet for the students to have access to the LMS canvas platform, etc.

As a note, although the details mentioned above look simply to achieve, took approximately two months to complete and ensure that the participating school will be ready to start the implementation of the project. This process started on January 2024 and the implementation of the project started on March 18th, 2024. In this period the project had two meetings with all the collaborators (via videoconference) and two sessions of professional development for the local instructors

Professional Development for the Local Instructors

Once the logistics of the project were organized and resolved, as was suggested in the feedback received from the implementation of the Pilot – Microgrid V1.0, the project developed a session of professional development for the local instructors.
Following is the agenda for the professional development

Microgrid V2.0 Professional Development Agenda

1. **Introduction of Participants**
   - Get to know each other.
2. **Student Requirements**
   - Students need: internet access, a computer, and an email account (preferably Gmail).
   - Make sure they know how to: use email, word processor, upload images, take screenshots.
   - Important: check emails daily; this is the project's main communication method.
3. **Navigating the Canvas Platform**
   - Explain the course structure.
   - Access Canvas and enroll students.
   - How to check grades.
4. **Teacher Strategy**
   - Roles of the Remote and Local Teachers.
   - Work outside of synchronous classes.
   - Local Teacher as the leader in asynchronous sessions.

5. **Synchronous Class Logistics**
    - Review the didactic agenda before each class.
    - Ensure the class is ready (connection and technical details).
    - Students should have their phone or a computer window open for Menti (communication app). If available, use the school internet to avoid using personal data.
    - Strategies to encourage active participation.
    - Hands-on activities during synchronous sessions.
6. **Asynchronous Class Logistics**
    - Set a dedicated time for students to access asynchronous tasks and ask questions.
    - The role of the Local Teacher in asynchronous activities.
    - Importance of completing the tasks.
7. **Projects**
    - Materials needed for the first project: solar phone charger.
    - Materials for the MicroGrid demonstration in the classroom.
    - Experiments students will conduct and how they will report them.
    - Preparation of the final report and presentation.
8. **Assessments**
    - Content exam and attitude survey before Week 1.
    - Formative assessments during the project.
    - Final content exam and attitude survey at the end.
    - Exit surveys for students and local teachers.
9. **Project Dates**
    - Week 1 starts on Monday, March 18th 2024
    - Week 8: May 17th -project presentations.
    - May 20th to May 30th Final assessments

Professional development was offered on two different days to ensure the maximum of local instructions participation. Despite the efforts to convocated and motivate the local instructors, less than 50% of the instructors participated in the professional development. This caused the researcher to spend many extra hours ensuring that the local instructors were ready to work with their students in synchronous and asynchronous meetings. From this experience is clear that in the next version of the project professional development will be mandatory.

Implementation of the project in the participating schools

When finalized the logistics arrangements, the project divides the rural schools in four cluster for the synchronous meetings, according to the days and times the school selected for the meeting

Mondays 11-13 CST (Arg 13-15) (Colombia 11-13) (México 10-12)
Tuesdays 8-10 CST (Arg. 10-12) (Colombia 8--10) (México 7--9)
Tuesdays 12-14 CST (Arg. 14-15) (Colombia 12-14) (México 11-13)
Fridays 10-12 CST (Arg. 12-14) (Colombia 10-12) (México 9-11)

The program started on the Week of Monday March 18^{th} and finished on the week of Monday May 13^{th}, being the last synchronous meeting on Friday May 17. All the sites have at least seven synchronous meetings
During the period of the project some schools have unexpected (or undeclared at the time of the organization) holidays or special activities days at the school. To solve this problem, all the synchronous meetings were recorded and placed on the platform LMS Canvas, allowing the local teachers and their classes that missed one synchronous meeting to see the video of the meeting previous the next synchronous meeting. Anecdotic data showed that many local instructors watched the videos with their students.

In the week called week #0 – before the start of the program, all the participants needed to be enrolled in the platform and complete the Content Knowledge pretest and the Attitude Survey towards STEM subjects and careers.

Between the week #1 and week #8, the participants participated in the synchronous meetings leaded by the remote instructor and complemented with the asynchronous learning leaded by the local instructor.

On the last week – week #8, students from the different communities of the program, presented their projects to their peers from different countries. The different teams from the schools produced a presentation and shared their experience with their peers. Following are some pictures extracted from their presentations

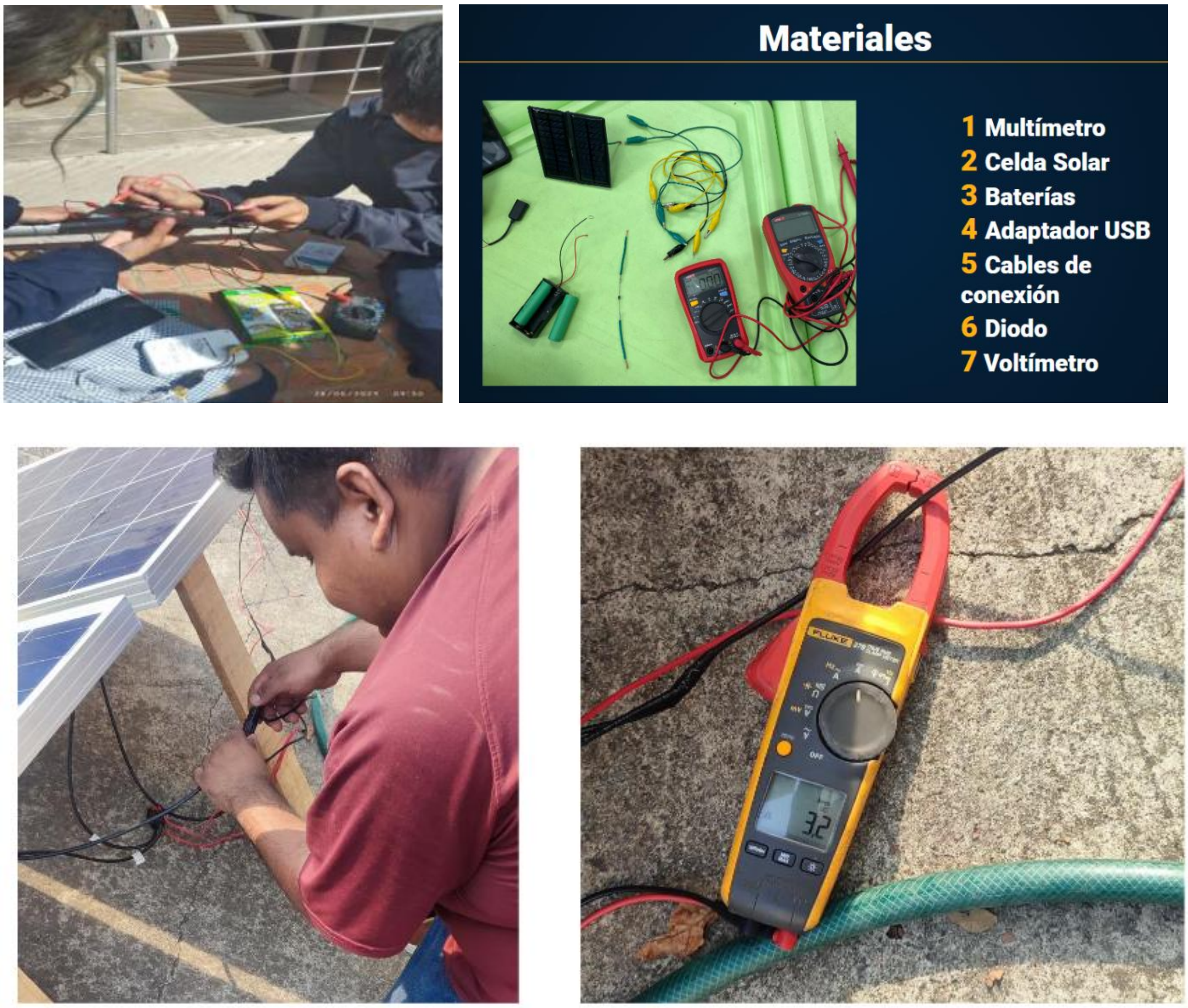

Figure 1. Students Testing Solar Panels on Different Communities

The last activity of the students regarding the project was to complete the Content Knowledge posttest, the attitude towards STEM subjects and careers, and an exit survey. These instruments were accessible via the platform canvas from May 20 to May 30th, 2024.

Data analysis of the results of the implementation of the project Microgrid V2.0

Analysis of the Content Knowledge changes during the project

To start the analysis, it is needed to clarify that from ALL the schools that participate in the project only 11 rural schools completed valid pre and post instruments. From these 11 schools N=146 students completed the Content Knowledge pre and posttest as shown below

Table 2. Participating Schools In The Project Microgrid V2.0 – Number Of Students Per School That Completed The Pre And Post Test

School

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Antonio Santos	20	13.7	13.7	13.7
	Bachillerato Mtlapa	19	13.0	13.0	26.7
	Bachillerato Xitlila	4	2.7	2.7	29.5
	Colegio Biffi	9	6.2	6.2	35.6
	IED Adolfo Gomez	17	11.6	11.6	47.3
	Instituto Lasalle	8	5.5	5.5	52.7
	Jerarquicos	24	16.4	16.4	69.2
	Jorge Arrieta	16	11.0	11.0	80.1
	Royal School	13	8.9	8.9	89.0
	Sargento Cabral	7	4.8	4.8	93.8
	UASLP Huasteca Sur	9	6.2	6.2	100.0
	Total	146	100.0	100.0	

At the beginning of the project

Of the 14 schools committed to participate in the project, 301 students enrolled in the platform Canvas. From them 276 students completed the pretest with a mean of 8.98 of 20 points. In this version, the pre and posttest were embedded in the LMS, to ensure that each student can do the test only once in each timeframe.

At the end of the project

The posttest was available after the last synchronous session of May 17th and remained open until May 30th. The posttest was completed by 155 students from 11 schools. Although there were send multiple reminders to the local instructors, the number of students that completed the posttest was 56% of the students that completed the pretest. Anecdotic data shows that: 1) some of the local instructors have changed positions during the project,2) the ages of the students were smaller that the project requested, and 3) that some classes were "optional" and not embedded in the curriculum as requested by the project. This last factor causes that in groups with large number of students, only a few performed the post test. The institutions that sponsored these schools did not do a good job preparing and managing their sites.

Table 3. Demographic Information Of The Participants That Completed The Posttest

Escuela

	Estudiantes por escuela	Porcentaje	
Antonia Santos	23	14.8	14.8
Bachilleraro Matlapa	19	12.3	27.1
Bachillerato Xitlila	5	3.2	30.3
Colegio Biffi	12	7.7	38.1
IED Adolfo Gomez	17	11.0	49.0
Instituto Lasalle	9	5.8	54.8
Jerarquicos	24	15.5	70.3
Jorge Arrieta	16	10.3	80.6
Royal School	13	8.4	89.0
Sargento Cabral	8	5.2	94.2
UASLP Huasteca Sur	9	5.8	100.0
Total	155	100.0	

Edad

		Estudiantes	Porcentaje
Valid	Menor de 13	3	1.9
	14.00	24	15.5
	15.00	37	23.9
	16.00	51	32.9
	17.00	24	15.5
	18.00	5	3.2
	Mayor de 18	10	6.5
	Total	154	99.4
Missing	System	1	.6
Total		155	100.0

Genero

		Estudiantes	Porcentaje
	Femenino	77	49.7
	Masculino	72	46.5
	Prefiero no decir	4	2.6
	Total	153	98.7
Incompleto		2	1.3
Total		155	100.0

Assessment of the changes in Content Knowledge of the participants that have valid pre and posttest

To assess if the intervention had a significant impact on the participants, a paired T-test was implemented on the 146 students with a valid pre and posttest. The results of the Content Knowledge test before the intervention were M1 = 8.59 (SD = 3.35), and after the intervention, they were M2 = 12.04 (SD = 4.09).

The paired t-test revealed a significant difference between the conditions, $t(145) = 9.632$, $p < 0.001$. Therefore, we reject the null hypothesis and conclude that the intervention had a significant impact on improving participants' content knowledge.

Table 4 Paired T Test Results Of All Students That Completed Valid Pre And Post Test

Paired Samples Statistics

		Mean	N	Std. Deviation	Std. Error Mean
Pair 1	Pretest	8.5890	146	3.35831	.27794
	Posttest	12.0479	146	4.09092	.33857

Paired Samples Test

		Paired Differences							Significance	
					95% Confidence Interval of the Difference					
		Mean	Std. Deviation	Std. Error Mean	Lower	Upper	t	df	One-Sided p	Two-Sided p
Pair 1	Pretest - Posttest	-3.45890	4.33928	.35912	-4.16869	-2.74912	-9.632	145	<.001	<.001

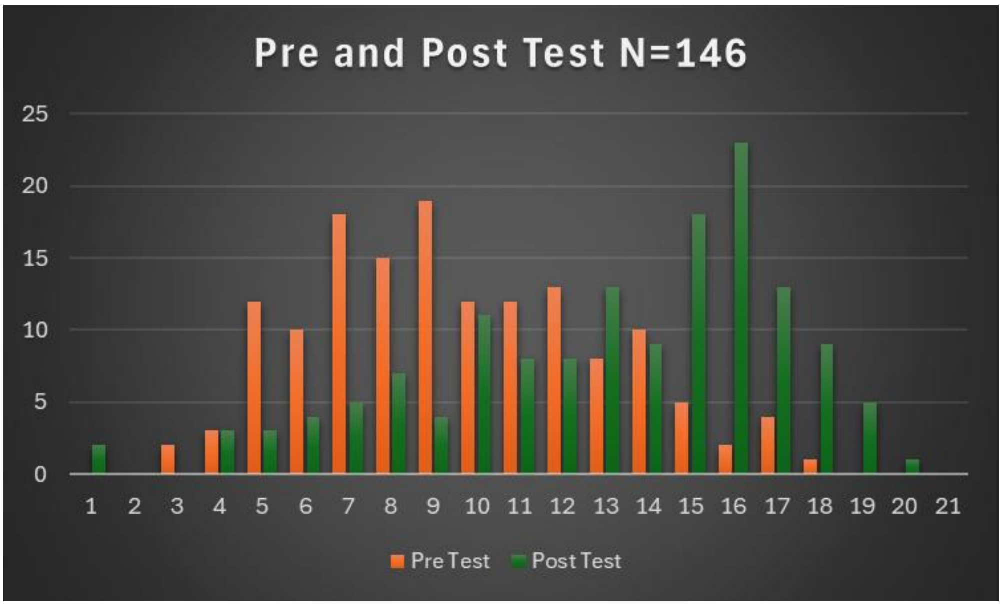

Figure 2: Visual Comparison of Pre And Post Test Results. The Horizontal Axis Represents the Score Of The Test And The Vertical Axis Its Frequency.

From figure 2 it is possible to see the positive shift of the results of the post test in comparison with the pretest. This figure helps to corroborate the results of the Paired T-Test, that shows a significant impact of the intervention on the large population (N=146).

A deeper analysis of a T-Test per school show that in many schools the project was successful, but in certain schools the project did not have a significative impact in the population involved as shown in the next table

Making a further analysis of the schools it is possible to see that:

- At the schools Bachillerato Matlapa , and Bachillerato Xitlita students did not participate in all the synchronous meetings, neither completed any asynchronous activities, also neither presented a final project to the community.
- Institute Lasalle and Royal school, both private and urban schools, placed the class as an optional and the local instructor did not use the grade of the class to give a grade to his/her students. Although many students from these schools completed the pre and posttest, students knew that the results of the posttest will have no impact in their grade.
- It is possible to see that the rest of the schools, with the exception of Sargento Cabral school showed a significant change in their content knowledge of the subject.

Table 5: Paired T Test Results of All Students That Completed Valid Pre And Posttest Per School

Paired Samples Test

	Paired Differences				Significance	
Escuela	Mean	Std. Deviation	t	df	One-Sided p	Two-Sided p
Antonio Santos	-4.20000	3.87434	-4.848	19	<.001	<.001
Bachillerato Matlapa	-.42105	4.32455	-.424	18	.338	.676
Bachillerato Xitlila	3.00000	5.88784	1.019	3	.192	.383
Colegio Biffi	-4.62500	3.46152	-3.779	7	.003	.007
IED Adolfo Gomez	-5.35294	3.99908	-5.519	16	<.001	<.001
Instituto Lasalle	-2.12500	4.01559	-1.497	7	.089	.178
Jerarquicos	-6.16667	3.77252	-8.008	23	<.001	<.001
Jorge Arrieta	-4.87500	2.27669	-8.565	15	<.001	<.001
Royal School	-1.15385	4.05886	-1.025	12	.163	.326
Sargento Cabral	-1.85714	5.27347	-.932	6	.194	.387
UASLP Huasteca Sur	-2.44444	2.18581	-3.355	8	.005	.010

Analysis of the impact of the asynchronous activities in the content knowledge gain of the participants.

One point that is interesting to explore is the impact of the asynchronous activities in the results of the posttest and in the gain of content knowledge by the students. Common sense dictates that if students are investing more time in the preparation of the activities of the course, then it is expected that their proficiency in the content will increase. But on the other hand, the amount of time that students participate in asynchronous activities can be a function of the involvement of the local instructor. It is important to remember that the local instructor is responsible for the implementation of the asynchronous learning time.

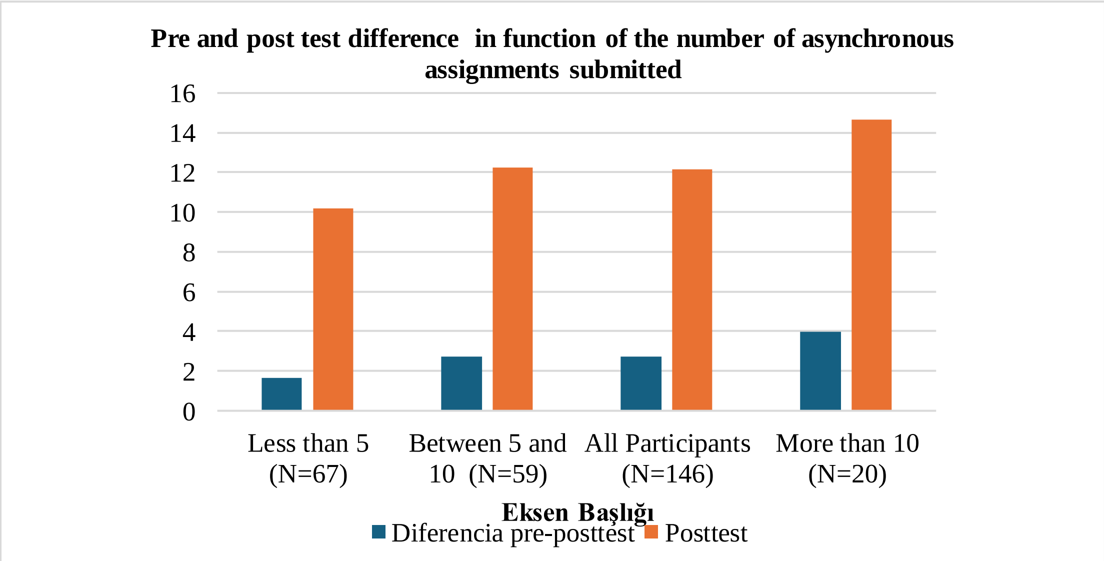

Figure 3: The Impact Of The Asynchronous Learning In The Change Of The Difference Between The Pre And Posttest.

Below is a graph that shows the relationship between the number of asynchronous activities submitted to the platform Canvas, and the difference between the pre and posttest per student

From Figure 3, it is possible to see that the students that submitted more asynchronous assignments, have the larger increase on the difference between their pre and posttest, as well as the larger mean of the posttest from all the groups. It indicates that the asynchronous assignments have an impact on the results of the posttest and on the knowledge gain of the students.

As indicated before, the time and efforts to motivate students to complete the asynchronous assignments is the prevue of the local instructor.

In summary, it is possible to see that the project has a significative impact on the content knowledge of students in many schools. Students that not only participated in the synchronous classes but also were active on the asynchronous activities had a larger change on the posttest score that those students that did not engage in asynchronous work. One of the potential reasons could be that the local instructor did not complain with the requirement to have at least one hour a week where students can access to the platform and work on their asynchronous assignments.

Conclusions

The implementation of the second time of the project (called Microgrid V2.0) has shown considerable progress in promoting STEM education in rural, underprivileged schools across Latin America. The project's main achievements include a significant improvement in students' content knowledge on renewable energy and electricity concepts, as demonstrated by a statistically significant increase in posttest scores. Moreover, students who actively engaged in both synchronous and asynchronous activities showed a more substantial improvement in their understanding of the subject matter.

One of the key takeaways from the project is the importance of hands-on learning in reinforcing theoretical concepts. The students' involvement in building functional microgrids and working on other renewable energy projects fostered not only academic learning but also practical skills that have the potential to benefit their communities directly. This integration of real-world applications into the learning process has been a vital factor in engaging students and increasing their interest in STEM fields.

However, several challenges were identified during this phase, most notably related to logistical constraints, including connectivity issues, holidays, and the inconsistent participation of local instructors in professional development sessions as well as leading the asynchronous learning. These challenges were more prominent in certain schools, which affected the overall success of the program in those schools. The level of involvement of local instructors in asynchronous activities played a critical role in student outcomes, suggesting that more emphasis should be placed on ensuring that local teachers are adequately trained and motivated to lead these sessions.

Despite these challenges, the Microgrid V2.0 project has demonstrated the viability of scaling STEM education in remote areas through a blended learning approach. The results affirm the project's potential for further expansion, with the caveat that improvements in teacher training, connectivity solutions, and institutional support are necessary for sustained success. Future iterations of the program should focus on addressing these gaps, making professional development mandatory, and ensuring that all participating schools integrate the program fully into their curriculum.

The Microgrid V2.0 project has not only advanced educational equity in rural communities but has also laid the groundwork for a replicable model of STEM education that can be applied in other underserved regions and can be developed with different contents. By combining remote learning with hands-on projects, the initiative has empowered students to become active contributors to solving local energy issues, which could inspire a new generation of innovators in the field of renewable energy.

Acknowledgements

The successful implementation of the Microgrid V2.0 project would not have been possible without the invaluable contributions of various individuals and institutions. We would like to extend our deepest gratitude to all the local instructors, whose efforts in facilitating the

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Chapter 6 - Challenges and Prospects of Cutting-Edge Technology in Education

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Chapter Highlights

- Digital literacy has become a necessity in this digital age; thus, the world is determined to prepare its citizens. In the recent past, world history has accelerated while handling the challenges of the pandemic. Consequently, the world population lived a decade in a few years, with several new initiatives commencing on an immediate basis.
- Nations and institutions invested heavily in technology for the continuation of educational activity with minimal impact. Due to these constraints, educators were compelled to think about the potential of technology to maintain and or enhance the learning of their students.
- Various advanced technologies that can be used for the enhancement of learning and engineering competencies achievement are being discussed here. The impact of Artificial Intelligence (AI) as an easy way out for completing different student tasks is also being highlighted.
- Educators are still contemplating how to make pedagogical gains from AI to have a positive influence on teaching and learning. It concludes that imagination supports critical thinking skills and problem-solving ability therefore, undue inclination towards the use of AI will end up in losing an individual's capacity or reducing the confidence in being able to use the imagination. This is feared to end up in eluding critical thinking skills and loss of problem-solving ability among future generations.

Introduction

In the post-Covid pandemic era, the digital landscape has undergone a profound alteration. In pre-COVID times it was considered a simple skill, but now digital literacy stands as an essential skill, allowing nations worldwide to equip their citizens for the complexities of the digital age (Eshet, 2004; Iordache et al., 2017; Ozturk, 2023). The catastrophic situation created by the global pandemic forced humanity to accelerate the timeline of history, compacting years of progress into a fraction of time. In response to this unprecedented transformation, nations and institutions alike have boarded a journey of significant investment in technology, determined to ensure the unified delivery of essential programs and services, to minimize disruptions (Siyabi, 2020; Alqahtani & Rajkhan, 2020; Khan, 2021). This wave of transformation largely affected educational institutions; instead, it has left a permanent mark on them. Educators are left with no choice and must navigate a swiftly evolving environment, where the integration of technology is not an option anymore but an imperative for optimal learning experiences. The accelerated shift towards digital domains has highlighted the urgent need for digital literacy, emphasizing the necessity of equipping students with this essential proficiency (Cakir et al., 2019; Khan et al., 2021). In this modern pedagogical landscape, technology is not just a tool but a foundation upon which the foundation of digital literacy is built. Yet, among this integration of analytical tools and innovative educational processes, educators face a contradiction of perspectives. Some view advanced technological tools as potential interferences in the classroom environment, while others perceive them as catalysts for engagement and interest in various learning activities (Sabzian et al., 2013; Muir-Herzig, 2004; Erişti et al., 2012). As an example, those who are in favor consider the can enhance accessibility, and collaboration can increase engagement and intractability but those who are opposed think that maybe technology leads to overreliance and potentially exacerbates existing inequalities (Harlin & Griffin, 2005).

This diversity of opinion sets the stage for an ongoing dialogue within educational circles, highlighting the complexities inherent in the union of technology and education. Indeed, technology in education has led to a transformation, fundamentally introducing the new way we approach teaching and learning. From interactive whiteboards to online learning platforms, the traditional classroom has changed into an innovative and interconnected space where students can engage with material in dynamic ways (Irving, 2006). It is within this context that this introduction sets the stage for a thorough exploration of the impact of technology on education, investigating its benefits, challenges, and promising future developments. Technology has drastically changed how we teach and learn. Students now have more ways than ever to explore their interests. While studies show technology can improve learning and cater to different learning styles, it also comes with challenges. Some people disagree about its benefits, pointing to studies that question its effectiveness. These studies highlight the importance of human interaction in learning, the cost of technology, and teachers' need for proper training (Kumar et al., 2008). Additionally, research highlights the importance of various factors like how technology is delivered, how students learn differently, and how teachers use it effectively, all of which play a crucial role in making technology beneficial for learning.

This chapter presents a voyage of discovery, examining the effectiveness of technologies to enhance the learning expedition and facilitate the attainment of engineering competencies. Rather than viewing these technologies as distractions, this chapter illuminates their potential as enablers of educational progress. Moreover, the chapter will also delve into the growing role of Artificial Intelligence (AI) and its profound impact on education. AI emerges as a multipurpose tool with the potential to simplify and enhance an uncountable of student tasks, presenting educators with the challenge of harnessing its pedagogical potential to create meaningful impacts on the teaching and learning processes (Mawson, 2003; Chugh, 2010; Ching & Roberts,2020).

From Essentiality to Indispensability

In 2007, Mark Warschauer's (2007) seminal work underscored a fundamental truth that resonates even more profoundly today “digital literacy has transcended the realm of luxury to become an indispensable necessity in navigating the complexities of the 21st century”. It is emphasized that the convergence of traditional literacies such as reading, writing, and critical thinking with new literacies like information fluency, multimedia comprehension, and digital communication, are all vital for success in our progressively digitized world. The advent of technology has opened unprecedented doors to information and communication, yet unequal access and inadequate skills can aggravate existing social and economic inequalities, creating a digital divide that transcends mere hardware access. This digital divide isn't solely about having access to devices; it's about the ability to critically evaluate the deluge of online information, distinguishing fact from fiction, and discerning credible sources from manipulative propaganda.

In an era where algorithms shape our online experiences and misinformation proliferates unchecked, digital literacy emerges as the empowering force enabling individuals to become informed citizens, responsible consumers, and active participants in the digital sphere. The rapid pace of technological advancement further underscores the urgency of digital literacy. With artificial intelligence, automation, and the gig economy reshaping the workforce, individuals who can leverage technology, adapt to change, and continuously acquire new skills will be best positioned to thrive in this dynamic environment. However, the path to digital literacy is fraught with challenges. The sheer volume of information available online can be overwhelming, while the rapid evolution of technology makes it challenging to keep pace. Moreover, issues of equity and access persist, with marginalized communities often facing significant barriers to technology and training. Education systems must respond by integrating digital literacy into their curricula, equipping students with the necessary skills from a young age. This encompasses not only technical proficiency but also critical thinking, responsible online behavior, and ethical considerations. Lifelong learning initiatives should be accessible to all, providing adults with opportunities to update their digital skills and remain relevant in the workforce.

Public libraries and community centers can play a crucial role in bridging the digital divide, a key barrier addressed by the United Nations' Sustainable Development Goal 4 (SDG 4) on quality education (Ydo, 2020; Allais et al., 2022). This goal, specifically Target 4.4, aims to increase the number of youth and adults who have relevant ICT skills, which aligns seamlessly with the efforts of these institutions. They can offer free access to technology, training programs, and workshops, empowering individuals with the essential skills to navigate the digital world. However, closing the digital divide is a shared responsibility. As highlighted in Target 4.5, SDG 4 emphasizes the need to eliminate gender disparities and ensure equal access to all levels of education and vocational training. This necessitates technology companies playing their part by designing user-friendly interfaces for diverse user groups, regardless of age, background, or ability. Additionally, promoting responsible online practices and combating the spread of misinformation as emphasized in Target 4.7, are crucial responsibilities of these companies to ensure a safe and inclusive digital environment.

The benefits of widespread digital literacy extend far beyond individual empowerment, echoing the spirit of Target 4.7's focus on global citizenship (Cassar, 2022). A digitally literate society, as envisioned by SDG 4, promotes innovation, collaboration, and problem-solving on a global scale, enabling individuals to actively participate in the 21st-century knowledge economy. Furthermore, such a society, as identified in SDG 4, enables citizens to hold their governments accountable, advocate for positive change, and participate meaningfully in the democratic process. This aligns with the wider objectives of SDG 16, which promotes peaceful and inclusive societies for sustainable development (Lazarus, 2020). In conclusion, bridging the digital divide requires a collaborative effort from public institutions, technology companies, and individuals. By working together, we can unlock the immense potential of a digitally literate society acquainted with advanced technology, promoting individual empowerment, and global, and responsible participation in a democratic world.

In essence, digital literacy has evolved from being an optional skill to becoming the cornerstone of success in the 21st century. By prioritizing digital literacy education, promoting equitable access, and encouraging responsible online behavior, we can unlock the full potential of technology to create a more informed, inclusive, and prosperous future for all. This journey, however, demands collective action from individuals, educators, policymakers, and technology companies alike. As technology continues its rapid evolution, let us not forget the human element; the power of critical thinking, responsible communication, and a commitment to building a better digital world resides not just in algorithms but in the hands of a digitally literate society. Building upon the framework outlined, preparing future generations for a sustainable future necessitates integrating these efforts within all levels of education, from primary to higher education. This aligns with Target 4.7 of SDG 4, which emphasizes the incorporation of sustainable development principles, including those on global citizenship, into education. This requires advancing critical thinking skills, environmental consciousness, and responsible decision-making capacities in students. By developing the coming generations on modernized grounds, we equip them with the knowledge and skills necessary to meet the challenges of a sustainable future for all. This includes recognizing an understanding of climate change, resource management, and social equity, preparing them to become responsible guardians of the planet and active participants in building a more sustainable world.

Digital Transformation

As the world experiences a huge digital revolution, the field of education stands at the forefront of transformative change. From classrooms enhanced with interactive whiteboards to the virtual corridors of online learning platforms, technology is reshaping the landscape of teaching and learning. This paradigm shift presents a tapestry of both exciting opportunities and complicated challenges, demanding a nuanced approach from educators, policymakers, and learners alike as they navigate the ever-evolving digital transformation.

Educational Implications

Some inspiring articles elaborate the educational impact of digital transformation takes center stage, underscoring the imperative for a balanced approach that harnesses the benefits of technology while addressing potential drawbacks. (Gree,2019; Mukul & Büyüközkan, 2023) Indeed, the integration of technology in education heralds a multitude of opportunities. Accessibility emerges as a cornerstone advantage, democratizing access to educational content and catering to diverse learning styles and backgrounds.

E-learning platforms offer flexible learning environments, adapting to individual needs and schedules. Interactive tools and simulations augment engagement, demystifying complex concepts and nurturing deeper understanding. Moreover, technology raises collaboration and communication, facilitating global connections among students and experts. However, the journey through this digital transformation necessitates a mindful navigation of potential challenges. The digital divide looms large, intensifying existing disparities in educational access and opportunity.

It is felt that overreliance on technology for learners is costing them their competency in critical thinking. As an example, a student who, when faced with a complex historical question, simply searches for, and copies the first answer they find online. This student avoids the crucial steps of critically analysing the information, considering different perspectives, and forming conclusions - all vital aspects of critical thinking.

Over time, repeated reliance on readily available answers without any critical engagement can hinder the development of critical thinking skills, making the student passive learners instead of active participants in the learning process. Furthermore, the digital realm presents a host of concerns, including issues of distraction, privacy infringement, and cyberbullying, prompting educators to teach responsible digital citizenship practices.

Strategies for Effective Navigation

Drawing from the insights of Michelle Green's report, key strategies emerge for navigating the digital transformation with efficacy (Green, 2019):

- *Focus on the Learner*: Technology should supplement, not replace, traditional learning approaches, with a central focus on the individual learner and the cultivation of critical thinking, problem-solving, and communication skills.
- *Prioritize Equity and Inclusion*: Ensuring equitable access to technology and providing necessary support is paramount to connecting the digital divide and mitigating inequalities, addressing concerns of affordability, infrastructure, and digital literacy.
- *Develop a Critical Lens*: Equipping students with the ability to critically evaluate online information is essential, strengthening media literacy and digital citizenship education to distinguish fact from fiction and identify credible sources.
- *Promote Collaboration and Community*: Technology serves as a instrument for collaboration and community building, connecting learners across geographical boundaries, yet it is vital to nurture a sense of belonging within the online learning environment.
- *Promote Responsible Digital Citizenship*: Collaboration between educators and parents is pivotal in encouraging responsible online behavior, emphasizing ethical technology use, cyber safety, and respect for others in digital spaces.
- *Embrace Ongoing Learning*: Given the rapid evolution of technology, educators must remain active, engaging in continuous professional development to adapt and acquire new skills.
- *Engage in Open Dialogue*: Collaboration among stakeholders (both internal and external) - educators, parents, policymakers, and technology developers and providers

- is essential, encouraging open dialogue to address concerns, share best practices, and devise collective solutions.

Strategies of Adaptation

By embracing these strategies, the transformative potential of technology in education can take learning to new heights by creating inclusive, engaging, and empowering learning environments. It is fundamental to recognize that technology is a tool, and its impact hinges on responsible implementation and a steadfast focus on learner-centric education. As we navigate the digital transformation, let us envision a future where technology catalyzes unlocking the full potential of learners, shaping a landscape where knowledge knows no bounds, and possibilities abound.

AI Impact on Education

Potential

Visualize a realm where personalized tutors crafted from algorithms guide students through tailored learning journeys, where adaptive curriculums dynamically mold to individual strengths and weaknesses, and where virtual mentors whisper words of encouragement through digital ears. This is the captivating charm of AI's potential in education, a symphony where rote memorization yields deep comprehension, and monotony surrenders to the exhilaration of discovery. In subsequent paragraphs, we delve deep into the transformative landscape of AI-powered language tutors, automated grading systems, and intelligent feedback loops, revealing how technology can evolve into a collaborative partner in the learning process, rather than a mere substitute for human ingenuity.

Unleashing the full pedagogical potential of AI presents educators with a profound challenge. As the custodians of knowledge, educators must tread delicately, harnessing the power of technology while safeguarding the sanctity of human interaction within the educational realm. This section embarks on a nuanced exploration of the sophisticated relationship between teacher and machine, examining the anxieties and ethical considerations that surface as artificial intelligence penetrates the venerable halls of learning. We confront questions of trust, autonomy, and the essence of humanity in a landscape where algorithms increasingly curate our understanding of the world.

Transformative Landscape

Considering AI's multiple impacts on this landscape, a beacon of hope emerges. Across classrooms worldwide, AI is revolutionizing the learning experience, offering personalized pathways tailored to individual preferences and pacing. Students collaborate seamlessly with virtual assistants, immersing themselves in interactive simulations that transport them across time and space. This chapter celebrates the transformative potential of AI in education, revealing how technology can democratize access to knowledge, stimulate student curiosity, and develop deeper understanding across a spectrum of disciplines.

Navigating the path with influence of AI is loaded with multiple challenges. The potential pitfalls of the change are to be aggressively confronted, addressing concerns surrounding algorithmic bias, overreliance on technology, and the ethical ramifications of AI-driven education. Effective strategies need to be explored for responsible AI integration. Moreover, efforts towards a responsible AI adaptation, advocating the importance of human oversight, the cultivation of critical thinking skills, and the assurance that technology supplements, rather than replace, the irreplaceable role of the educator needs to be actively pursued.

Shaping the Future

Let us imagine stepping into the AI-enabled classroom, to witness both the potential and the threats, and to engage in the vital discussion about carving the future of education in the age of intelligent machines. Whether embraced with open arms or approached with reasonable skepticism, one undeniable truth remains: the mutually beneficial relationship between humans and machines has commenced, and its echoes will resonate throughout the classrooms of tomorrow.

Imagination and Critical Thinking

Imagination and critical thinking, often perceived as separate faculties, are deeply knotted, each complementing and enhancing the other. Here a symbiotic relationship between imagination and critical thinking is emphasized, illuminating how imagination catalyzes deeper analysis and innovative problem-solving. Critical thinking thrives on the ability to explore various possibilities and visualize alternative solutions. Imagination acts as a powerful springboard, propelling individuals beyond immediate observations and allowing them to construct mental simulations. By engaging in imaginative exploration, individuals challenge the status quo and seek out innovative solutions, furthering a sense of ingenuity and creativity.

Embracing Diverse Perspectives through Imagination

Imagination serves as a bridge to understanding diverse perspectives, enabling individuals to empathize with others and appreciate different viewpoints. Through imaginative exercises like role-playing, individuals develop empathy and engage in more delicate critical analysis, building bridges across differing viewpoints and developing deeper understanding. At its core, critical thinking is about generating new ideas and solutions, and imagination serves as the spark that kindles innovation. By engaging with imaginative thinking, individuals get free from conventional patterns and explore unexplored territories, generating fresh perspectives and proposing novel solutions to complex problems. Curiosity is essential to critical thinking, and role of imagination is vital in nurturing this curiosity. By adopting curiosity and openness to new experiences, imagination propels individuals to ask deeper questions, challenge norms, and seek understanding beyond the surface level, driving exploration and critical analysis. Studies show that recognition of imagination's importance in critical thinking is not new and these further demonstrate that engaging in imaginative activities improves critical thinking skills across diverse groups (Lau, 2011; Alkhatib, 2019; Baumtrog, 2017; Valett, 1983).

Additionally, research on cognitive processes reveal significant overlap between critical thinking and imagination, underscoring their inter-reliant nature. While enhancing imagination is crucial for critical thinking, it's essential to strike a balance between imaginative exploration and rigorous analysis. Unconstrained imagination can lead to influenced conclusions, highlighting the need for environments that encourage both creative expression and critical analysis. In an era dominated by artificial intelligence, conserving imagination and originality in education is vital for new generations. AI excels at data processing but lacks the creativity and empathy inherent in human imagination. By prioritizing imaginative thinking in classrooms, we arm future generations with the competencies to navigate complex problems and shape the world creatively. In summary, imagination and critical thinking are indispensable associates on the journey toward deeper understanding and effective problem-solving. By fostering imagination, we empower individuals to think creatively, explore diverse interpretations, and innovate solutions, adopting a more well-rounded and adaptive approach to navigating the intricacies of the world.

The Crossroads of Innovation

Innovation stands as the basis of progress, revolutionizing industries and reshaping societal landscapes by accompanying in unique advancements and transformative changes. Its essence lies in the insistent quest of improvement, driving industries to reimagine processes, products, and services in ways that redefine norms and uplift standards. Across industries, innovation catalyzes evolution, propelling technology to new heights, optimizing operational efficiency, and inspiring the development of innovative solutions. Whether it's the disruptive impact of artificial intelligence in automation, the sustainable initiatives revolutionizing renewable energy, or the blend of technology and finance in the realm of fintech, innovation continually reshapes the competitive terrain and strengthens economic growth. However, the profound effect of innovation transcends the confines of industries, extending its influence deep into the fabric of society. It responds to pressing societal needs, addressing global challenges like climate change, healthcare accessibility, and socio-economic inequalities. Innovation fuels the creation of solutions that strive not only for profitability but also for inclusivity and sustainability, driving meaningful change that influences the lives of individuals worldwide. It is in this connection between societal needs and innovative solutions that we witness revolutionary advancements, from the democratization of information through digital connectivity to the growth of smart cities designed for sustainability and improved living standards.

In the modern-day landscape, the interaction between industries and society catalyzes innovation further. Alliances between diverse sectors encourage cross-pollination of ideas, leading to exponential growth and complicated solutions that address complex challenges. Moreover, the digital era has democratized innovation, empowering individuals, and small entities to contribute to transformative changes previously reserved for bigger corporations. This democratization not only accelerates the pace of innovation but also diversifies its sources, tapping into a broader pool of creativity and expertise to drive progress. As industries and societies continue to evolve, innovation remains the important cornerstone, driving synergies that propel people toward a more interrelated, sustainable, and equitable future. At the juncture of pixelated possibilities and dusty tomes lies the future of learning - a boundless horizon shimmering with the promise of innovation. This chapter invites you to stand at this crossroads, to witness the convergence of digital fluency and educational evolution, and to deliberate the queries that lie at the heart of shaping tomorrow's classrooms.

Digital Literacy

In this digital age, literacy in the language of technology is no longer a choice, but a passport to participation. Just as fluency in reading and writing once unlocked libraries and kindled minds, digital literacy now opens doors to a treasure trove of knowledge and enables individuals to navigate the complicated pathways of the digital world. From accessing crucial information to collaborating with peers across continents, digital skills have become the basis of educational development, ensuring equitable access to opportunities and knowledge in a world increasingly defined by ones and zeros. But education refuses to be confined to textbooks and screens.

Innovation, propelled by the fuel of technology, is restructuring the very essence of learning. Imagine classrooms transformed into immersive virtual landscapes, where students step into the heart of history or dissect virtual frogs. Envision adaptive learning platforms that tailor content to individual needs and learning steps, fostering personalized educational expeditions. These are not mere futuristic fantasies, but signs of the potential that lies inactive within the intersection of creativity and technology. As educators embrace innovative tools and reshape curriculum to harness their power, the future of learning promises to be not just transformative, but deeply compassionate in nature, developing associations and collaborations, and filled with the pleasure of discovery.

Standing at this intersection, however, demands not just wonder, but also cautious reflection. The route forward is paved with challenges - ethical considerations regarding data privacy and algorithmic bias, navigating the potential downsides of technological dependency, and ensuring equitable access to digital resources across socio-economic divides. These are not obstacles to be ignored, but bridges to be built, demanding open dialogue, critical thinking, and an obligation to guaranteeing that technology serves, not replaces, the irreplaceable role of human connection and empathy in the learning process.

Challenges in the Adaptation of Technologies

Technology, like a double-edged sword, unlocks doors to progress while casting intricate shadows of challenge. As we embrace its transformative power in education, we must also acknowledge the intricate dance it initiates with human limitations and biases. This chapter delves into the minefield of challenges that lie at the intersection of technology and education, urging us to tread cautiously and adapt wisely.

Responses of Generations X and Z

The digital wave, surging relentlessly, can leave some generations stranded on the shores of resistance. Generation X, raised on the tangible hum of typewriters and the comforting weight of paperbacks, may view the digital transformation with concern. Educators, often themselves from this generation, may face internal obstacles in fully accepting and employing new technologies. This creates a delicate dance - bridging the gap between generations, raising trust, and demonstrating the tangible benefits of technological integration, without overlooking the valid concerns of experience.

On the other end of the spectrum stands Generation Z, digital natives swimming fluently in the sea of algorithms and pixels. Yet, overreliance on technology can cause its own set of challenges. Attention spans decrease, critical thinking muscles weaken, and the attraction of virtual worlds threatens to eclipse the richness of real-world experiences. The challenge exists in harnessing the technological competence of this generation while promoting a healthy balance, warranting that technology remains a tool, not a crutch, and real-world engagement stays firmly woven into the cross-stitch of learning. A recent article published in "The Guardian" highlights the necessity of regulation with regards to the use of generative tools (Adams,2024). The article elaborates on a study where majority (more than 50%) of undergraduate students in the UK used these tools to complete their assigned tasks and obtain high grades. It also explains how the core objective of the assessment was overlooked by simply copying and submitted the generated response by the tools to attain excellence without any associated learning.

Risk Mitigation:

Technology, for all its benefits, comes with its own Pandora's box of hazards. Data breaches, algorithmic bias, and the potential for cyberbullying emerge large. The burden lies on educators and administrators to become gatekeepers, implement robust security measures, endorse responsible digital citizenship, and raise healthy skepticism towards information found online. Risk mitigation demands vigilance, awareness, and ongoing dialogues about safe and ethical technology use in educational spaces.

Non-regulated Use of AI

Artificial intelligence, the mysterious genie in the technological bottle, whispers the promise of personalized learning and educational revolutions. Yet, its unregulated use in classrooms brings ethical dilemmas to the forefront. Questions of student privacy, algorithmic transparency, and the potential for aggravating existing inequalities demand rigorous discussion. This challenge demands a collaborative approach, involving educators, policymakers, and AI developers, to ensure that AI in education serves its true potential as a tool for human learning, not a driver of division or bias.

In conclusion, the adaptation of technology in education is not a victory lap, but a tightrope walks. Acknowledging and tackling the challenges - generational divides, digital dependency, risk mitigation, and ethical AI integration - is not a sign of weakness, but a crucial step towards achieving a future where technology enhances, not replaces, the irreplaceable magic of human interaction and discovery in the classroom. Remember, the way forward rests not in blind enthusiasm, but in cautious collaboration, critical thinking, and a promise to using technology as a bridge, not a barrier, to human learning in all its vibrant complexities.

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Chapter 7 - 21st Century Skills: Student's Creative Thinking Skills Through STEAM Integrated Project Learning

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Chapter Highlights

- Creative thinking skills are one of the skills that need to be improved to face the challenges of the 21st century. In line with technological developments, this article explores an innovative approach to improving creative thinking skills through the application of integrated STEAM (Science, Technology, Engineering, Arts, and Mathematics) project-based mathematics learning. STEAM, as an interdisciplinary approach, offers a rich and diverse framework for sparking student creativity through cross-disciplinary exploration.
- This research is descriptive research with a qualitative approach. This research aims to look at students' creative thinking skills in the STEAM integrated kite project based on the worksheets provided.
- The results of the research analysis provide empirical evidence that through project activities, students have different and original ideas expressed in the STEAM integrated kite project.
- This research provides empirical evidence that implementing integrated STEAM projects can develop creative thinking skills for students, as well as the importance of combining art and mathematics in learning contexts and creating opportunities for students.

Introduction

21st-century skills are needed in every area of life. In the context of the current situation, its influence on education is very significant, because education is the main point that must be developed in facing changes in the 21st century.(Fideli & Aliazas, 2022). The education system must continue to adapt to society's expectations in the 21st century to remain relevant in a world full of uncertainty regarding the labor market (Hazaymeh, 2022; Ozturk, 2023). For students to achieve the authentic learning required in the 21st century, they must be actively engaged in effective learning environments and hone 21st-century skills, such as analytical thinking, problem-solving, and working collaboratively (Alismail, 2015). 21st-century education provides opportunities for students to find new solutions to problems or find different ways, students are constantly finding their approaches to problems.

Education requires learning methods that not only aim to understand concepts but also apply these concepts in everyday life situations (Darling-Hammond et al., 2020), Education is emphasized to encourage skills that must be possessed in the 21st century, including critical thinking, problem-solving, creativity, scientific literacy, communication, and collaboration. (Zayyinah et al., 2022; Kemdikbud, 2023).

Creative Thinking Skills in Mathematics

The main source of creativity comes from the structure of Guilford's intellectual model (Runisah et al., 2016). In general, creativity is a term that covers aspects of thinking skills, which can be understood as a broad ability to think diversely or divergently (Siraj-Blatchford, 2007). The skill of creative thinking plays an important role in observing situations from different perspectives and helps to be more open, flexible, and consider every opportunity that arises, as well as trying various approaches without ever giving up (Qadri et al., 2019).

Creative thinking has significant relevance in the world of work, as well as in the personal and societal spheres, thus highlighting the urgency of developing creative thinking in educational settings (Rosen et al., 2020). Creative thinking skills require students to solve problems and make decisions in their lives, as well as improve overall cognitive and intellectual development (Yazar Soyadı, 2015; Putri et al., 2023).

Of the several skill components used in the PISA test framework, one of the components used is creative thinking skills (OECD, 2023). Creative thinking skills are very important for students because they have an important role in the learning process and in solving mathematical problems. Setting standards for creative thinking in the context of mathematics education can involve an analytical framework for designing a framework for developing creative thinking in mathematics learning (Lince, 2016). Students are expected to develop creative mathematical thinking skills by solving various forms of mathematical problems (Johar et al., 2023).

Guilford introduced that creative thinking is a divergent thinking process, which includes fluency (generating many ideas), flexibility (generating various ideas from a variety of different perspectives), originality (generating unconventional ideas), and elaboration (adding details to ideas to develop them) (Ritter & Mostert, 2017; Wechsler et al., 2018; Bicer et al., 2021). Efforts to improve creative thinking skills in mathematics learning provide opportunities for students to be able to compete in the world at large and improve students' cognitive and affective abilities.

To improve students' creative thinking skills, it is necessary to take into account the framework and design of mathematics learning that can facilitate the improvement of mathematics skills (Tanujaya et al., 2017). Developing a framework for improving creative thinking skills can be done through STEAM integrated learning design (Putri et al., 2023; Syukri et al., 2022). The STEAM approach can influence creativity, levels of self-confidence, and motivation, and can indicate a potential correlation between creativity and increased self-efficacy (Sotiriou & Bogner, 2020; Jia et al., 2021).

Kite Project Integrated STEAM

One multidisciplinary approach that can be applied to mathematics learning in the 21st century is STEAM (Science, Technology, Engineering, Arts, and Mathematics). STEAM is a learning approach that has characteristics of 21st-century learning (Sigit, 2022). STEAM is an acronym derived from STEM with the additional inclusion of the letter "A," emphasizing the important role of the arts in a cross-disciplinary approach to strengthening creativity (Lu et al., 2022). The interdisciplinary approach has attracted great attention because of its emphasis on developing students' skills in solving complex and real-life problems (Jia et al., 2021).

Collaboration in STEAM education will help students collect, analyze, and solve problems and understand the relationships between problems. Using a project-based learning approach integrated with STEAM can be a solution to improve creative thinking skills that are relevant to the 21st-era (Zayyinah et al., 2022). By integrating assignments in the form of STEAM projects into the curriculum, students are allowed to observe the relevance of mathematics and science learning at school with its application in solving problems in the real world outside the school environment. (Vale et al., 2022). The STEAM project invites students to solve problems related to everyday life by thinking comprehensively based on the five STEAM disciplines.

One aspect of traditional game culture in Indonesia that is closely related to students' daily activities is the tradition of flying kites (Budiman et al., 2023). A kite is a thin sheet of material with a frame that is flown into the air and held by a string connected to a controller. Kites use wind to glide through the air and are internationally known as a means of recreation. Kite flying is part of Indonesia's traditional cultural heritage and is generally played by children in open fields. However, not only children, adults, and the elderly also take part in kite flying. There is even a kite festival event held to preserve traditional game culture.

With a background in real-world activities, students are no strangers to the term kite. Applying STEAM-integrated Project Based Learning in the learning process facilitates students to plan learning activities, engage in collaborative projects, and create products (Putri et al., 2023). Implementing kite making project learning, provides an approach that is close to the real world of students (Isamer et al., 2023).

By exposing students to new and contradictory problems, they will construct their thinking to find truth and clear reasons (Delima et al., 2022). In learning mathematics, students' creative thinking skills are needed to carry out investigations, ask questions, and make decisions (Doa et al., 2018). The result of thought that is expected to reach its peak is the process of creation (Shalihah et al., 2020).

The problems underlying this research are based on the need for 21st-century skills, including several studies showing students' difficulties in learning geometry. This causes students' creative thinking skills in solving mathematical problems to be difficult to develop, especially those related to Geometry (Utami et al., 2017; Nurwijayanti et al., 2018; Rahayu & Jupri, 2021). So, this research aims to describe students' creative thinking skills through a STEAM-integrated kite-making project, the problem given is related to calculating the area of a flat shape and making a flat-shape construction.

Method

This research is descriptive research with a qualitative approach. Descriptive research aims to describe a phenomenon along with the characteristics inherent in the research topic (Nassaji, 2015). This research focuses on describing the creative thinking skills of junior high school students through STEAM-integrated learning on a kite-making project in mathematics learning with the topic of geometry.

Context and Participants

This research was carried out at a junior high school in the city of Yogyakarta, Indonesia. The population of this study included all class VII at SMP Yogyakarta, Indonesia. The research sample consisted of 20 students selected using a purposive sampling technique. The purposive sampling technique involves selecting samples with a specific purpose (Creswell, 2012). The reason for using purposive sampling in this research was because it took into account the research objectives which focused on the creative thinking skills of class VII students. The research was carried out for three weeks with four face-to-face meetings in the classroom and one face-to-face interview to verify the validity of the data. In the first week, a pre-test was carried out as an introduction and delivery of material related to various flat shapes on the topic of geometry. In the second week, the project process was carried out by making a kite design and carrying out field trials and analysis of the results of the project that had been created, followed by interviews in the third week.

Data Collection and Analysis

This research collected data from photos, videos, observations, interviews, and students' work in the form of kites they created. The validity of the data was then verified through triangulation in semi-structured interviews with students. In this research, data analysis follows the framework developed by Milles and Huberman (Miles, 1994).

Table 1. Indicators of Creative Thinking in The Kite Project

Indicators	
Fluency	Sketches and constructs products deftly and skillfully with the right tools
Flexibility	Uses math, technology, and science concepts to solve problems
Originality	Skills in thinking and producing different kite projects from each group
Elaboration	Students' skills in constructing projects according to the given procedures, as well as identifying the strengths and weaknesses of their designs.

The learning process is structured and implemented based on the Engineering Design Process (EDP) steps developed by Hester & Cunningham (2007), the steps include: *ask, imagine, plan, create, and impro*ve. The STEAM analysis on the student worksheet is shown in Table 2 below.

Table 2. STEAM Analysis

STEAM Component	
Science	Applying lift, Newton's Law III, and Bernoulli's Law
Technology	Internet to find information on kite and kite making, as a technology that is created
Engineering	Design a kite, test, observe and analyse the results of the kite that has been made
Art	Decorating the kite
Mathematics	Geometry (flat area)

The project outcome assessment guide uses the assessment guidelines by (Padmi et al., 2021) as in the following table.

Data was collected from the beginning to the end of the program through direct classroom observations and concluded through semi-structured interviews with students. To assess project results, the assessment instrument uses five open questions based on 4 aspects of creative thinking by Torrance (1972), Creativity is assessed using assessment indicators such as fluency, flexibility, originality, and elaboration. The assessment process uses a rubric summarized in Table 3.

Table 3. Student Assessment Guide

No	Capable Learners	Intermediate (1)	Advanced (2)	Advanced (3)	Very Advanced (4)
1	Sketch and construct products deftly and skilfully with the right tools	Learners are able with full teacher assistance	Need with teacher assistance	Able without teacher assistance	Able to create and complete other requirements
2	Use maths, technology and science concepts to solve problems	Unable to connect various concepts to solve problems	Need with teacher assistance	Able to identify technology required.	Learners are also able to identify other subjects that are also related
3	Skills in thinking and producing different kite projects from each group	Not able to construct and generate ideas	Need with teacher assistance	Able to construct products	Able to construct, and also propose more sophisticated tools or procedures more sophisticated
4	Students' skills in constructing projects according to the given procedures, as well as identifying the strengths and weaknesses of their designs.	Not able to identify weaknesses and strengths of their design.	Able to identify, although the identificatio n still incomplete	Able to identify weaknesses and strengths of their design They	Not only do they identify the weaknesses and strengths of the design, students also propose ideas for improvement.

Results

The following is given the results of data analysis for each aspect of students' creative thinking skills in STEAM integrated project learning.

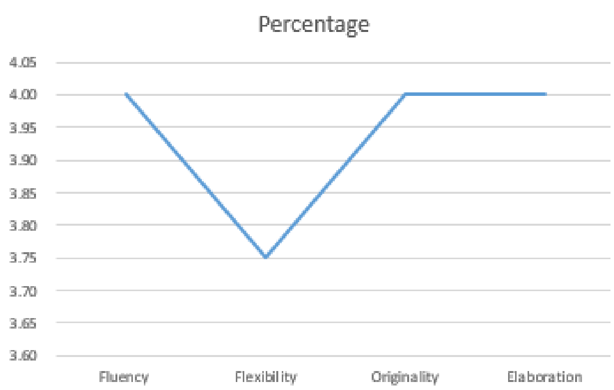


Figure 1. Percentage of Creative Thinking Skills

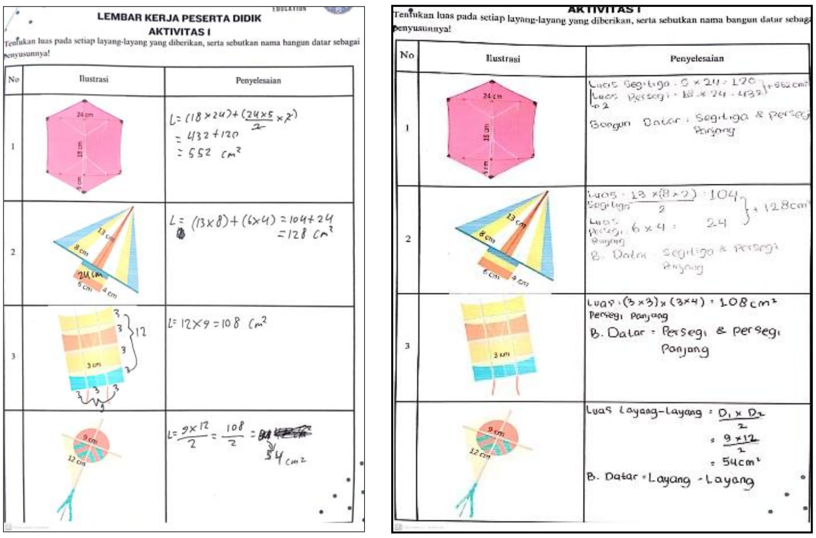


Figure 2. Student Responses on The *Pre-Test*

The results of the analysis provide information that students can demonstrate their skills in developing creative ideas based on creative thinking indicators. Students are able to develop projects according to the procedures that have been given, as well as identify and analyse the strengths and weaknesses of their designs. The graph shows the flexibility indicator with a frequency of 3.75%. This means that there are obstacles for students in using mathematics, technology, and science concepts to solve problems. In general, for the indicators of creative thinking, students have reached the very advanced stage.

Before starting the lesson, the researcher conducted interviews with students as research subjects, along with conducting a pre-test. In the first learning in the classroom, students were given worksheets containing geometry problems, students analyzed and provided various ways of solving to determine the total area of the flat shape in question. The *pre-test* consisted of four description questions. At this stage, the researcher involved 20 students who were divided into four heterogeneous groups. The following are students' responses to the first problem given in the *pre-test.*

The results of the pre-test showed that students had a good understanding of algebraic operations and basic geometry concepts, especially in terms of calculating the area of flat shapes. Students have different views on generating creative ideas to solve problems.

In the scope of mathematics didactics, based on the Engineering Design process (EDP), project learning in STEAM-integrated kite making begins with the Ask stage. The Ask stage implemented is shown in the following figure 1 below.

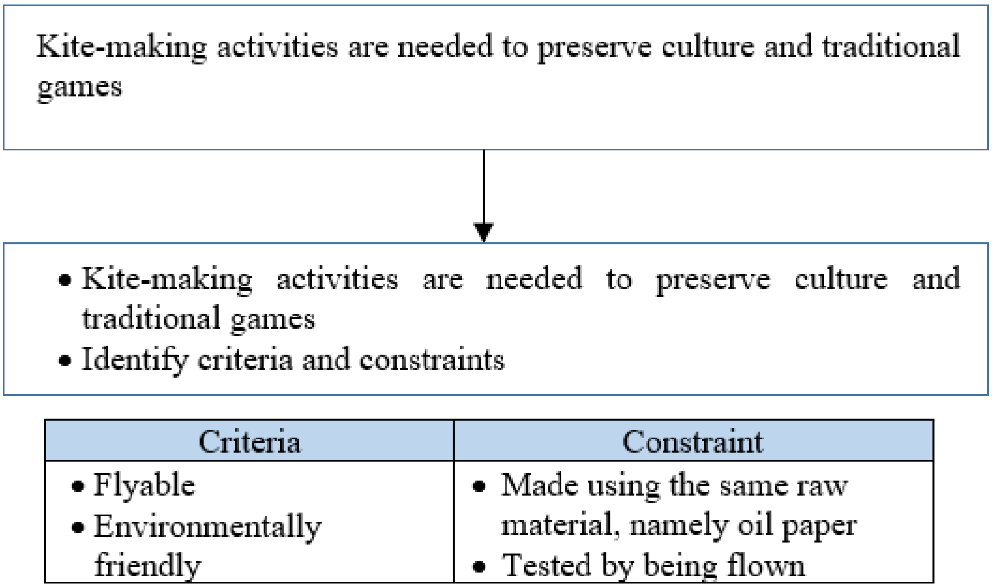
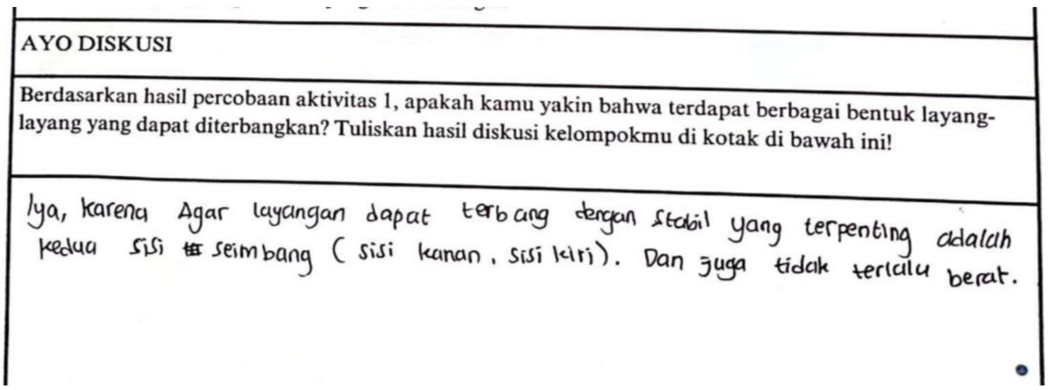


Figure 3. Ask Phase

Students are given problems related to kite projects that must be made with several success criteria and limitations that must be considered. The following are the problems contained in the worksheet at the Ask stage. Furthermore, students answer the questions using the ideas and responses of students in the discussion of each group.



AYO DISKUSI
Berdasarkan hasil percobaan aktivitas 1, apakah kamu yakin bahwa terdapat berbagai bentuk layang-layang yang dapat diterbangkan? Tuliskan hasil diskusi kelompokmu di kotak di bawah ini!
Iya, karena Agar layangan dapat terbang dengan stabil yang terpenting adalah kedua sisi seimbang (sisi kanan, sisi kiri). Dan juga tidak terlalu berat.

Figure 4. Problems And Student Responses At The Ask Stage (In Indonesian)

LET'S DISCUSS
Are you sure that there are different shapes of kites that can be flown? Write the results of your group discussion in the box below!
yes, because in order for the kite to fly stably the most important thing is that both sides (wings) are balanced and also not too heavy.

Figure 5. Problems And Student Responses at The Ask Stage (In English)

Berdasarkan hasil pekerjaan siswa pada tahap *Ask*, setiap kelompok memiliki argumen disertai gagasan bahwasanya berbagai macam bentuk bangun datar dapat menjadi penyusun dalam pembuatan layang-layang untuk dapat diterbangkan. Dalam hal ini, siswa menunjukan aspek berpikir kreatif dengan memberikan gagasan utama dari pemikiran kritis, kreatif, inovatif, dan keterampilan teknis (Šmitienė & Kesylė, 2022)

The second stage of the STEAM Design Engineering process (EDP) is imagine, where students find solutions and conjectures from a problem based on discussion and collaboration in groups. As an apperception, the researcher as an instructor will review the material previously learned and remind students of the concept of flat shapes. Figure 6 shows student activities at the imagining stage.

Figure 6. Imagine Activity

Implementation in the third stage, namely plan. At this stage, students make a design that has been agreed upon based on the results of discussions in each group member. In this plan stage, students apply their creative thinking skills. Making innovations by creating new concepts, making extensive use of imagination, or changing something that already exists into an interesting new form (Gafour, 2020). At this stage, students discuss with group members to determine the ideal kite design to be flown.

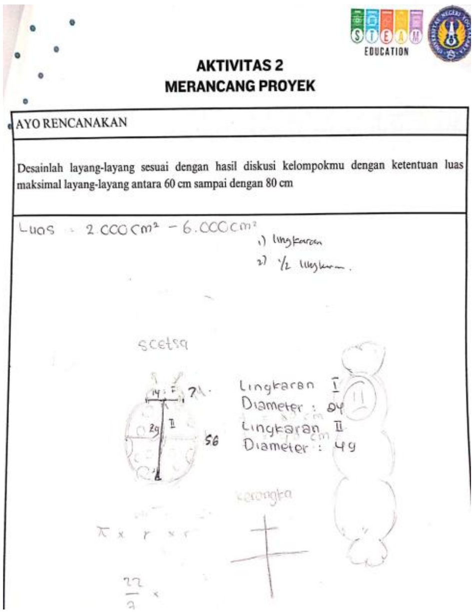


Figure7. Problem 2 And Student Responses at the Plan Stage (In Indonesian)

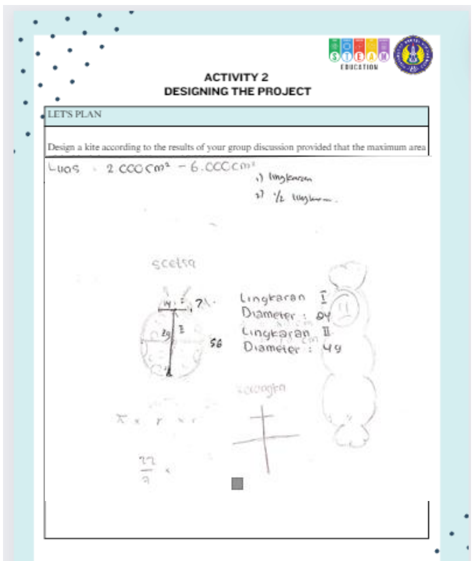


Figure 8. Problem 2 And Student Responses at The Plan Stage (In English)

Not only the design, each group also provided details of the size of the kite to be made. The following are the results of interviews with students related to the designs that have been made.

T : 'What kite shape will you make'

S : 'We will make a beetle kite'

T : 'What flat shapes will be used as constituents?'

S : 'Here we use a circle. There are two shapes of circles. One full circle, and half circle'

T : 'What is the total size you used?'

S : 'Here the total area is 53.3 cm'

T : 'Are you sure your kite will be ideal when you fly it?'

S : 'It seems ideal miss

It can be seen from the various designs that have been made by students, each of which provides original and different designs from each group.

The fourth stage of the project is created, at this stage, students apply the plan that has been developed to create the project. The students made kites collaboratively. Each group collaborates to make a product using the tools and materials available, previously an ideal size has been made in making a kite that will be tested to be flown.

Figure 9. Create Activity

Figure 9 shows the students' activities in the kite-making process at the create stage, showing their ability to solve problems, such as calculating the area of paper used and making the right decisions. The following is the work of the kite project that has been made by each group (Figure 10).

Figure 10. Results of Creative Thinking on STEAM Integrated Kite Project

After making the kite, they tested it by flying it. Figure 11 illustrates the trial process of flying the kite. The researcher monitored the student's progress according to the steps set out in the lesson plan, with the proviso that the teacher was not allowed to intervene in the student's learning process.

Figure 11. Testing And Analysis Phase

The final step is to evaluate the product by analyzing the kites that have been made.

The researcher as the instructor asked about the procedure and the results. Figure 12 shows one of the student's responses in analyzing the results of the kite project that has been made. The following are the questions and instructions for the kite flight test stage.

1. Can you fly the kite you made? Give your reasons!
2. What are the problems with the kite you have made?
3. What should you fix on your kite?
4. Redesign the kite according to your analysis!
5. Were there any obstacles you encountered in this kite-making project? If so, please mention them!

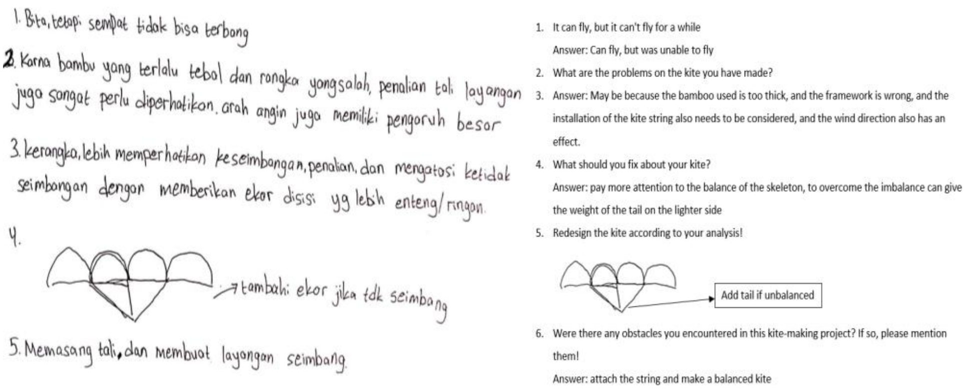


Figure 12. Testing And Analysis Phase

In this activity, students use flat shapes such as circles, squares, hexagons, and triangles as the constituents of their kite products. Overall, the research process provides adequate results based on the implementation of STEAM learning and creative thinking aspects.

Students can apply STEAM and fulfill the indicators of creative thinking skills in project learning from each stage of the Engineering Design Process (EDP). Indicators that appear in student activities and answers include fluency, flexibility, originality, and elaboration.

Discussion

Engineering Design Proses (EDP) developed by Hester & Cunningham (2007), It starts with the Ask stage. At this stage, students define the problem and identify needs, make sure there is a need for a solution, and identify criteria and constraints (Vale et al., 2022) As the importance of creative thinking skills in learning mathematics is paramount, identifying needs is the most common way to understand the research implementation.

In the implementation of STEAM integrated project learning, teachers are not allowed to intervene in student activities. Students are motivated to ask each other to their group mates, so that groups can work together if there are students who need help understanding the material (Isamer et al., 2023). Based on semi-structured interviews with students, doing project activities relevant to real life is more interesting and exciting, while the process of implementing project activity-based learning can train students to think creatively to be more significant. STEAM-based learning can train critical thinking, creativity, and 4C skills (Mengmeng et al., 2019).

The techniques in the STEAM steps are adaptable, collaborative, and aware of the latest teaching and learning trends. Previously, a similar study was conducted by Mustopo (2019) conduct a study on a project related to determining the area of a flat plane. In this way, students can understand and apply the information in everyday life through kite-making and maintaining traditional games.

Creative thinking can be defined as a series of actions of the mind used by a person to respond to certain objects, problems, situations, or efforts in dealing with certain events or problems, which are carried out based on the ability of the individual concerned (Yazar Soyadı, 2015). From the results of the project, students have proven their creative thinking skills. In learning mathematics, students' creative thinking skills are needed in conducting investigations, asking questions, and making decisions (Dolapcioglu & Doğanay, 2022). Been a long time since I saw you. Before leaving Indonesia very soon. (Costantino, 2018). Through learning with STEAM-integrated project activities, providing information related to student's creative thinking skills (Zayyinah et al., 2022).

The integration of creative and critical thinking has been emphasized in the literature in the last decade (Wechsler et al., 2018). Students with good creative thinking skills are expected to be able to use their ideas to solve a mathematical problem in a different, correct, and appropriate way (Johar et al., 2023). The importance of thinking skills has a significant impact on overall student achievement in mathematics, one of which is on the PISA test

(Qadri et al., 2019; Aziz & Irwan, 2020).

Based on these findings, shows that creative thinking skills can be improved more significantly through learning with project activities. So that through STEAM-integrated projects in kite making can monitor and train students' creative thinking skills in using procedures, concepts, mathematical tools, and facts to strengthen skills using numbers, symbols, and information seen in real-world contexts.

Conclusion

Learning through the STEAM-integrated kite-making project that has been implemented, provides an overview of students' creative thinking skills in solving mathematical problems, as well as providing skills collaboratively

The implemented learning supports the achievement of 21st-century skills such as teamwork, communication, creativity, problem-solving, and critical thinking. The analysis results provide information for each creative thinking indicator to reach the Highly Proficient stage. In the fluency, originality, and elaboration indicators, the percentage results are 4.00%, while for the flexibility indicator with a percentage of 3.75%. By combining materials from various disciplines in the context of learning through the STEAM approach, these values include knowledge in a relevant context as well as skill development that is interesting and engaging for students. This research is limited to describing creative thinking skills on kite-making projects with the topic of geometry material for junior high school students.

Recommendations

Based on the results of the research that has been done, of course, there are still many mistakes and shortcomings. So there are several suggestions for further research in the implementation of learning using the STEAM approach. Such as, it is necessary to research to measure the effectiveness of the STEAM approach in mathematics learning with other 21st-century skills variables such as critical thinking ability, mathematical communication ability, and collaboration ability.

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Chapter 8 - Sustainable Development Through STEM Education

Behiye Akçay

Chapter Highlights

- In this study, the contribution of STEM education (Science, Technology, Engineering and Mathematics) to sustainable development is discussed. STEM education is identified as an important tool to support economic growth and achieve sustainability goals. The study examines the historical developments in STEM education, its integration with sustainability and the societal contributions of these processes.
- STEM education aims to provide students with skills such as critical thinking, problem solving and creativity. These skills are essential for generating innovative solutions to global problems such as climate change, resource depletion and environmental degradation. The study emphasizes that STEM education should be implemented with an interdisciplinary approach at the K-12 level. It also provides recommendations to increase women's participation in STEM fields and reduce gender inequalities in these fields.
- The strong connection of STEM education with sustainable development goals shows that this education plays a critical role for a sustainable future not only in the environmental but also in the economic and social spheres. The study recommends that educational policies and pedagogy approaches should be restructured in a way that enhances the contribution of STEM to sustainable development. In this direction, it is stated that STEM education is a foundation for building an innovative, inclusive and sustainable world.Teachers' Views on Providing Cultural Heritage Education in Visual Arts Lessons.

Introduction

Sustainable development has emerged as a critical global priority in the face of escalating environmental, social, and economic challenges. As nations strive to achieve the United Nations' Sustainable Development Goals (SDGs), education plays an indispensable role in equipping individuals with the knowledge, skills, and values necessary to address complex global issues. Among the various educational approaches, STEM (Science, Technology, Engineering, and Mathematics) education has proven to be a transformative tool for fostering innovation, critical thinking, and problem-solving. By integrating sustainability principles into STEM curricula, learners are empowered to devise practical solutions to pressing challenges such as climate change, resource depletion, and sustainable urbanization.

This study explores the pivotal role of STEM education in promoting sustainable development. It delves into the historical evolution of STEM, its integration with sustainability frameworks, and its contributions to societal progress. Furthermore, the research examines how STEM education can bridge gaps in gender equity and workforce readiness, ensuring a more inclusive and capable generation prepared to tackle future challenges. By aligning educational practices with sustainability goals, STEM education paves the way for a resilient and innovative future.

Historical Background of STEM Education and Sustainability

Throughout history, economic power has often paralleled the prioritization of education systems and innovations in sustainability. From this perspective, STEM (Science, Technology, Engineering, and Mathematics) education is important for economic development and leadership (European Commission, 2017). The evolution of STEM education and sustainability has been marked by pivotal historical milestones (Figure 1). The period of World War II (1939-1945) highlighted the critical role of science and technology in national security, spurring significant advancements in these fields. The establishment of the U.S. National Science Foundation (NSF) in 1950 institutionalized STEM education, prioritizing research and innovation to address societal needs (NSF, 2024).

The launch of Sputnik by the Soviet Union in 1957 catalyzed global interest in STEM education, prompting the U.S. to establish NASA in 1958 to compete in the space race. Awareness of environmental sustainability began to intertwine with STEM education during the 1972 Stockholm Declaration, which emphasized the need for global cooperation on environmental issues. In the 1980s, the Brundtland Report provided a foundational definition of sustainable development, shaping policies that integrated sustainability into educational frameworks (World Commission on Environment and Development, 1987).

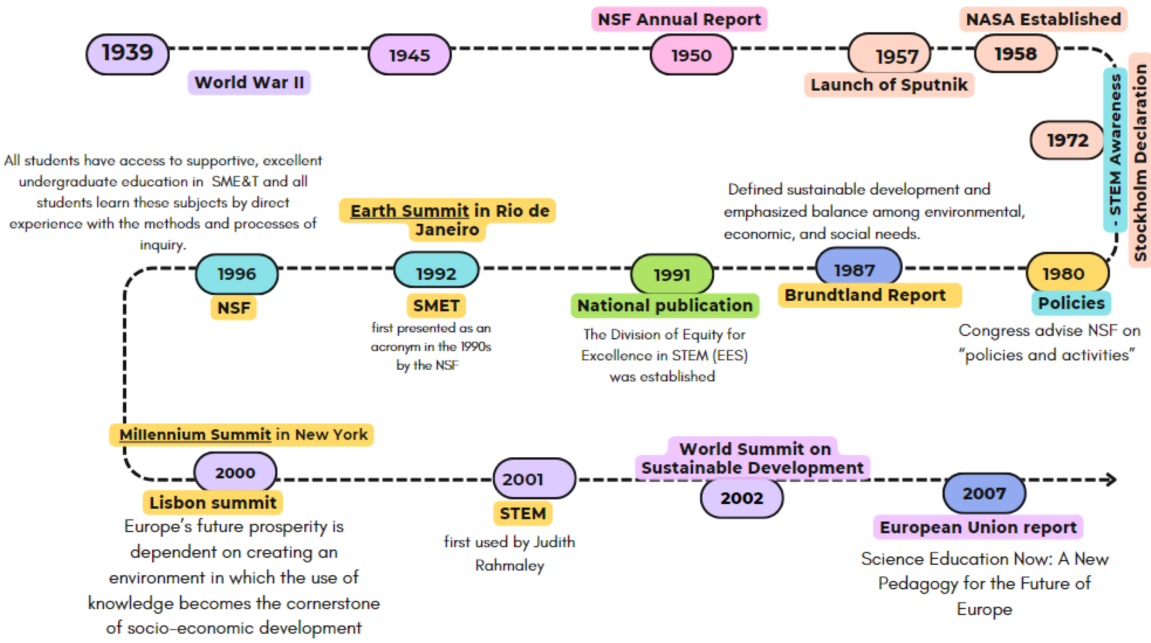

Figure 1: History of STEM Education and Sustainability From 1939 to 2007

During the 1990s, the focus on STEM expanded with the introduction of terms like SMET (Science, Mathematics, Engineering, and Technology). Key events, such as the 1992 Earth Summit in Rio de Janeiro, underscored the role of STEM in addressing global sustainability challenges. By 2001, the term STEM was officially adopted, signifying a unified approach to science and technology education. Judith Rahmaley first used the concept of STEM in 2001 as an Assistant Director of the NSF's Education and Human Resources Directorate (Akarsu, Okur Akçay & Elmas, 2020). STEM education aims to equip students with critical thinking, problem-solving, and creativity to address real-world challenges (Bybee, 2013; Honey, Pearson & Schweingruber, 2014; National Research Council [NRC], 2014; World Economic Forum [WEF], 2020). This progression continued with the 2002 World Summit on Sustainable Development, which stressed the integration of STEM into global environmental strategies (United Nations [UN], 2015b).

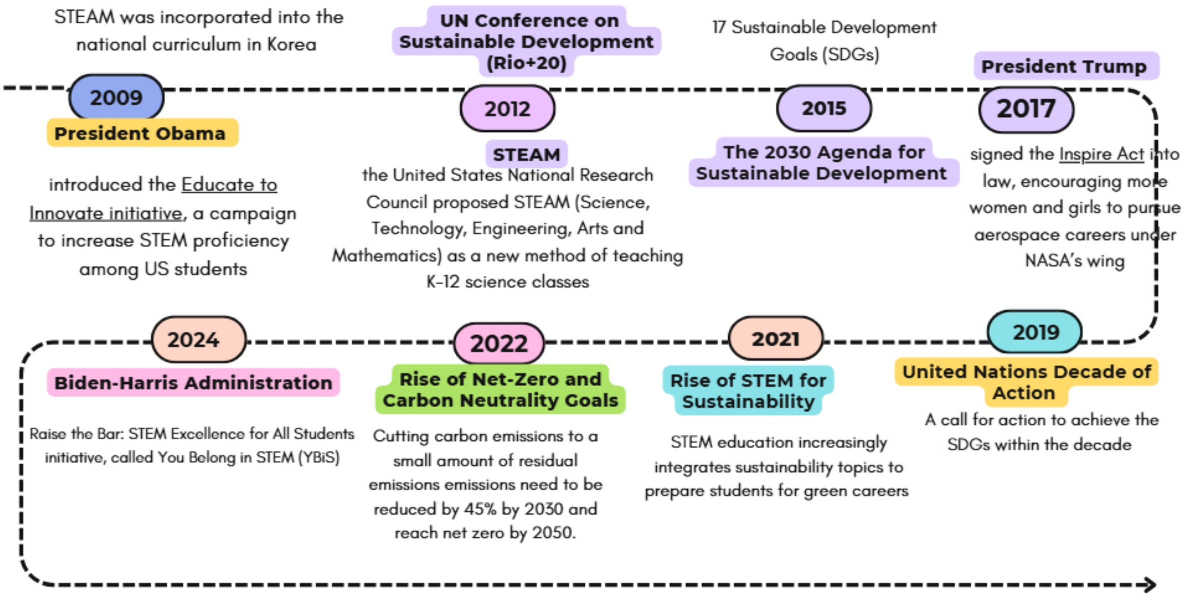

Figure 2: History of STEM Education and Sustainability From 2009 to 2024

In recent years, STEM education has become vital to building a sustainable society for future generations. As we confront challenges like climate change, resource depletion, and environmental degradation, empowering students with STEM skills is essential for developing innovative solutions. Education for sustainability is becoming a priority as the world faces escalating environmental crises that endanger the long-term health of our planet. A strong foundation in STEM equips learners to address global issues, fostering a future where sustainability is central to progress (Kataeva, 2024; Grigoleit-Richter, 2017).

In the 2000s, initiatives like the Lisbon Strategy and the Millennium Development Goals reinforced the global commitment to STEM as a driver of economic and environmental progress (Figure 2). President Obama's 2009 "Educate to Innovate" initiative expanded STEM by integrating arts (STEAM) into the national curriculum to foster creativity and innovation. Similarly, the 2012 Rio+20 Conference underscored STEM's role in sustainable development, with the U.S. National Research Council advocating STEAM as an effective teaching methodology for K-12 education (NRC, 2014).

The introduction of the Sustainable Development Goals (SDGs) in 2015 provided a global roadmap linking STEM to objectives such as quality education and climate action. In 2017, the INSPIRE Act, signed by President Trump, aimed to enhance STEM opportunities for women and girls. Recently, the Biden-Harris administration's 2024 "You Belong in STEM" initiative has focused on equity and inclusion in STEM education, emphasizing excellence for all students (U.S. Department of Education, 2024).

The Contribution of STEM Education to Society

STEM education plays a critical role in promoting scientific literacy, enabling individuals to tackle complex issues such as climate change, healthcare challenges, and economic stability. A scientifically literate society is better equipped to make informed decisions on sustainability and innovation, aligning with global goals for a better future (European Union [EU], 2017; Organization for Economic Cooperation and Development [OECD], 2018).
A robust STEM education is essential for preparing scientists and engineers capable of driving technological advancements and addressing pressing sustainability goals. For example, STEM professionals have been pivotal in renewable energy innovation and resource conservation efforts, which contribute to achieving the United Nations' Sustainable Development Goals (Bybee, 2013; WEF, 2020).

Policy makers and industry leaders leverage STEM education to guide students toward careers that align with future global challenges, including green jobs and climate resilience. Such efforts ensure that STEM remains a foundational pillar for economic growth and societal well-being while addressing the urgent need for sustainability-focused solutions (NSF, 2024; UN, 2015b).

Pedagogical Approaches in STEM Education

STEM education has evolved through diverse pedagogical approaches aimed at enhancing learning outcomes. Initially, the four disciplines of Science, Technology, Engineering, and Mathematics were taught separately, focusing on essential knowledge, skills, and attitudes related to STEM competencies. This deductive approach, which presents concepts and deduces logical implications supported by practical examples, has been foundational in early STEM education (NSF, 2020a).

John Dewey, in 1996, critiqued the isolation of disciplines in education, arguing that it hindered students' ability to understand interconnected subjects and relate learning to daily life. This perspective led to the adoption of the Inductive or Inquiry-Based Science Education (IBSE) approach, which promotes learning through observation and experience. IBSE allows students to internalize knowledge through self-discovery and has been particularly effective in engaging underrepresented groups, such as girls, by building confidence in science (Mpofu, 2019; United Nations Educational, Scientific and Cultural Organization [UNESCO], 2017).

European countries such as Germany, Austria, and Norway have implemented diverse STEM approaches tailored to their educational priorities and cultural contexts. OECD (2018) highlights gaps in STEM competencies, emphasizing the need to integrate knowledge, skills, attitudes, and values into interdisciplinary frameworks. These initiatives promote innovative teacher education and incorporate arts into STEM (STEAM) to address challenges like gender gaps and curriculum rigidity (Honey, Pearson & Schweingruber, 2014; Mpofu, 2019). Entrepreneurial pedagogy has gained traction as a method to align STEM education with real-world challenges. Popularized by Allan Gibb in the early 2000s, entrepreneurial pedagogy fosters values-driven learning and emotional engagement. This approach enhances students' sense of purpose, agency, and connectivity, preparing them for adaptive and collaborative roles in STEM fields (Gibb, 2002; Lackéus, 2018). Moreover, it links socio-cultural values with scientific inquiry, helping students understand how societal norms influence innovation and aligning with frameworks like the Next Generation Science Standards (NGSS Lead States, 2013).

Gender Inequality in STEM Education and Careers

Gender inequality in STEM education and careers continues to be a significant issue worldwide, with girls and women facing persistent barriers despite their academic achievements. Garcia-Penalvo et al. (2022) has emphasized the importance of awareness programs to attract more girls into STEM fields and support women in research careers. These initiatives, combined with specialized career guidance and assistance programs, aim to address structural inequalities. Ensuring equal access to STEM education is essential not only as a human rights issue but also for achieving the 2030 Agenda for Sustainable Development, which contributes to global goals such as peace, equality, and human progress (OECD, 2018).

Certain countries, such as Lithuania and Bulgaria, have maintained higher female representation in STEM fields, a trend attributed to historical Soviet policies that emphasized STEM education, supported women in STEM careers, and challenged gender stereotypes (Grigoleit-Richter, 2017; Kataeva, 2022). Kazakhstan has built on this legacy by establishing elite STEM schools to promote STEM careers among talented students (Kuchumova et al., 2024).

In Turkey, empowering girls and women and ensuring their active participation in social life, education, and employment are key priorities in national policy. Specific programs aim to enhance women's engagement in development and increase female employment. Women in Turkey receive 20% more support than men in entrepreneurship initiatives. Programs such as "My Mom's Job is My Future" and "Engineer Girls of Turkey" are specifically designed to increase female participation in STEM, fostering a more gender-balanced workforce (Yapar, 2019).

Although girls often perform as well as or better than boys academically, they frequently lack confidence in STEM-related subjects, which can hinder their long-term engagement and success in STEM fields (WEF, 2020; NSF, 2020a). International assessments such as TIMSS and PISA show that the gender gap in STEM achievement is narrowing in early education. The 2023 PISA Report highlights that boys score slightly higher than girls in mathematics (by an average of 9 points), while performance in science demonstrates near parity. Among younger students (ages 6–15), there are minimal performance differences, indicating equal potential for STEM achievement (OECD, 2018). However, disparities remain in higher education and career preferences. Women tend to graduate in fields like biology, chemistry, health, and welfare, whereas men dominate in engineering, technology, physics, and earth sciences (Eurostat, 2024; UNESCO, 2017). Despite their academic achievements, women hold only 25% of jobs in STEM-related professions (Eurostat, 2024).

Addressing these disparities requires targeted solutions. The European Commission has highlighted the effectiveness of gender-sensitive teaching methods, such as Inquiry-Based Science Education (IBSE), which fosters real-world learning contexts to build girls' interest and confidence in STEM (European Commission, 2017). Providing female role models and mentors is another proven strategy for inspiring girls to pursue STEM careers and closing the gender gap in education and professions (UNESCO, 2017).

Structural barriers, including non-inclusive curricula, stereotype-reinforcing teaching practices, and a lack of visible female role models, continue to limit progress. Self-efficacy, defined as an individual's belief in their ability to succeed in STEM, plays a critical role in overcoming these challenges. Pedagogical strategies that promote gender-neutral environments and collaborative, inquiry-based learning can significantly enhance self-efficacy among both girls and boys, fostering equitable engagement and success in STEM (Eurostat, 2024). Increasing the participation of girls in science and boosting their self-confidence in STEM fields is crucial not only for promoting gender equity but also for expanding the talent pool needed for innovation and sustainability. These efforts are vital for creating an inclusive and capable workforce, driving progress and advancing STEM careers worldwide (Eurostat, 2024; WEF, 2020).

STEM Education and Workforce Needs

Globally, there is a significant shortage of graduates in STEM fields, coupled with a high demand for skilled STEM professionals in the workforce. Recent data highlights that countries like Germany, France, and Italy are investing heavily in STEM initiatives to address these shortages. In particular, projections indicate that these nations will face over 0.5 million STEM job openings each by 2030 (UN, 2015b). According to Eurostat (2024), fewer than 10% of European students graduate in natural sciences, mathematics, or statistics, with countries like Bulgaria, Cyprus, and Hungary reporting figures as low as 3%. To combat this trend, STEM education reforms and curriculum updates are being implemented across the EU and beyond to engage students in STEM from an early age.

In Turkey, a comparison of university placement exam results from 2020 to 2024 reveals notable gender-based trends in career choices. Male students predominantly pursue careers in engineering, information, and communication technologies, while female students are more likely to choose careers in healthcare and related fields. These trends highlight the ongoing need for gender-sensitive strategies to balance STEM participation across disciplines and genders (Council of Higher Education, 2024).

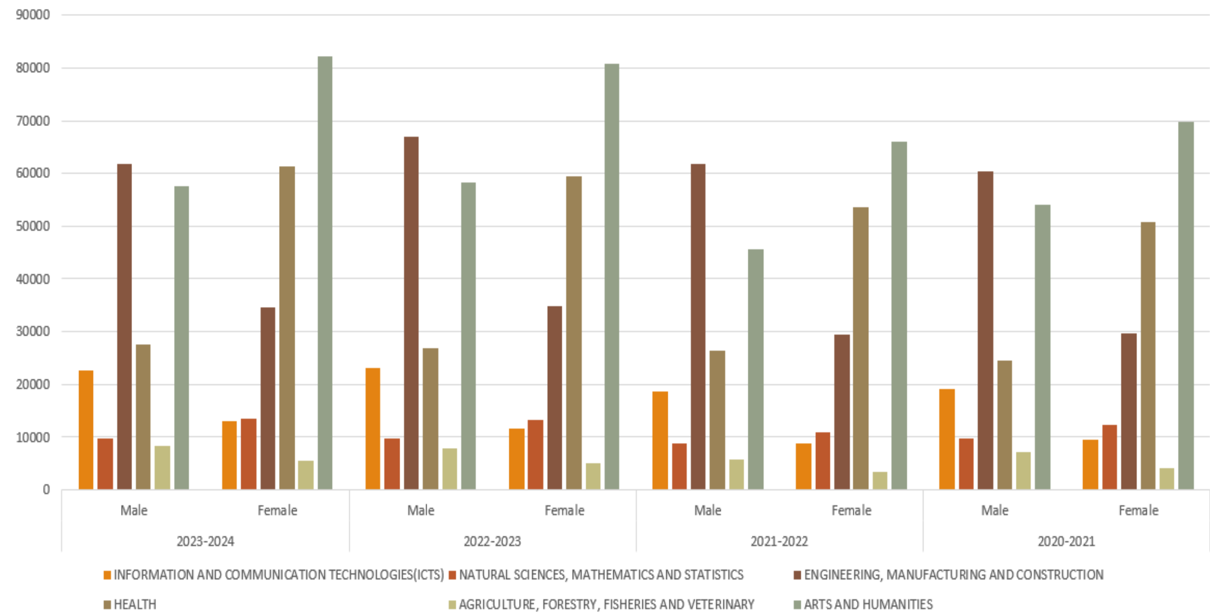

Figure 3: STEM Placement Rates by Gender in Turkey (2020–2024)

Figure 3 illustrates the placement rates of male and female students in STEM fields over the last four years based on data retrieved from the Higher Education Information Management System (Council of Higher Education, 2024). These trends highlight the critical need for STEM education in addressing workforce challenges. Preparing qualified STEM professionals is essential for technological advancement, innovation, and economic growth. Moreover, increasing female participation in STEM can create a more inclusive workforce, fostering diversity and societal progress.

In the United States, the demand for STEM professionals remains high, particularly in engineering, computer science, and healthcare sectors. The gender disparity in STEM employment is also evident globally, with men dominating engineering and computer-related professions, while women are more represented in healthcare and life sciences. Initiatives to bridge these gaps, such as targeted mentorship programs and industry-academic partnerships, are essential to fostering a more inclusive STEM workforce (Eurostat, 2024; EU STEM Coalition, 2023).

The Connection Between STEM and Sustainable Development

STEM education plays an indispensable role in achieving sustainable development by equipping individuals with the skills needed to address global challenges such as climate change, resource depletion, and urbanization. As nations strive to meet the United Nations' Sustainable Development Goals (SDGs), STEM emerges as a critical tool for fostering innovation, enhancing employability, and creating solutions to complex environmental and social problems (UNESCO, 2017). Specifically, STEM education aligns closely with SDG 4 (Quality Education), SDG 7 (Affordable and Clean Energy), SDG 13 (Climate Action), and SDG 15 (Life on Land), emphasizing innovation, sustainability, and the skills necessary to address global challenges. Over decades, this integration has fostered the development of competencies essential for sustainable societal progress, highlighting STEM's significant contribution to achieving the SDGs (Figure 4) .

One of the key contributions of STEM to sustainability lies in its ability to empower students to think critically and solve problems. By integrating sustainability into STEM curricula, students are prepared to engage with real-world challenges such as renewable energy, waste management, and sustainable agriculture (NRC, 2012; OECD, 2018). For example, community-based projects that involve local sustainability issues encourage students to take ownership of their learning and connect theoretical knowledge with practical applications (NSF, 2020a).

The integration of sustainability in STEM education is not only beneficial for environmental goals but also for economic development. Studies by the OECD (2018) demonstrate that effective STEM education contributes to sustainable economic growth by fostering innovation and preparing students for green jobs. This dual impact highlights the importance of aligning STEM with sustainable development to create a workforce capable of driving change in key sectors.

Moreover, STEM education promotes global competencies by fostering an understanding of interconnected systems and encouraging interdisciplinary approaches. Initiatives like the Environmental Education and Climate Change course introduced in Turkey in 2022 exemplify how STEM can be leveraged to raise awareness and equip students with the tools to tackle pressing global issues (Council of Higher Education, 2024).

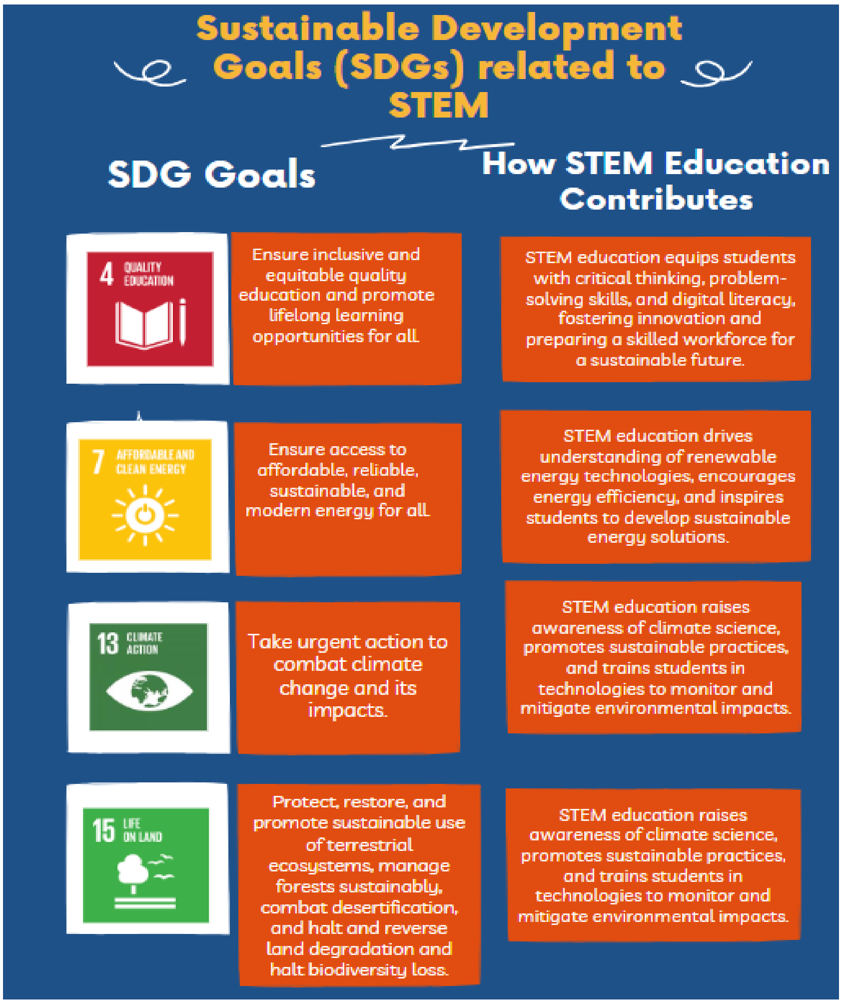

Figure 4: Sustainable Development Goals (SDGs) related to STEM

The integration of sustainability in STEM also encourages entrepreneurial thinking, enabling students to identify opportunities for innovation that align with sustainable practices. Programs that emphasize project-based and problem-based learning further enhance this capability, preparing students to become active contributors to a sustainable future (Lackéus, 2018). As the world moves toward achieving the 2030 Agenda for Sustainable Development, the alignment of STEM education with sustainability goals remains a top priority. By fostering critical thinking, creativity, and a sense of responsibility, STEM education ensures that the next generation is well-equipped to address the multifaceted challenges of sustainable development (UN, 2015a).

Table 1: Integration of STEM and Sustainable Development Goals (SDGs)

Time period	Sustainable Development Goals (SDGs)	STEM Education and Career Choices
1980s	The World Conservation Strategy, introduced in 1980, outlined principles of sustainable development, emphasizing conservation and the responsible use of natural resources.	A Nation at Risk report, published in 1983, highlighted the decline in education in the U.S., emphasizing the importance of science and math as critical subjects for global competitiveness.
		The first STEM initiatives emerged in the 1980s, focusing on science and math education in schools to prepare students for workforce readiness.
1990s	The Earth Summit in 1992 introduced Agenda 21, a comprehensive global action plan for sustainable development.	STEM and workforce programs were implemented globally to address the growing demands of the tech industry and prepare a skilled workforce.
	The Kyoto Protocol, adopted in 1997, established legally binding greenhouse gas reduction targets for industrialized nations.	
2000s	The Millennium Development Goals (MDGs), established in 2000, consisted of eight objectives focused on reducing poverty, hunger, and disease, while promoting education, gender equality, and environmental sustainability.	The U.S. introduced STEM Education Acts to enhance investment in STEM fields and support workforce development.
		Global STEM Initiatives: Countries adopted STEM-focused curricula to foster competitiveness and drive innovation.
2015	Sustainable Development Goals (SDGs): Succeeded the MDGs with 17 comprehensive goals addressing poverty, health, education, clean energy, and climate action.	STEM Workforce Demand: Increasing demand for STEM careers, particularly in green energy and sustainable engineering.
Late 2010s	The Paris Agreement, adopted in 2015, seeks to limit global temperature rise, enhance climate action goals, and promote sustainable practices globally.	STEM to STEAM Movement: Integrating the arts into STEM curricula to foster creativity and develop interdisciplinary skills.
		Focus on STEM Diversity: Initiatives aimed at increasing gender and racial diversity within STEM fields..
2020s	Increased Emphasis on SDG Progress: Nations are urged to accelerate the implementation of the SDGs, with a particular focus on climate action, sustainable cities, and quality education.	Net-Zero and Green STEM Careers: Growing career opportunities in sustainable engineering, renewable energy, and environmental sciences.
	The United Nations Decade of Action (2020–2030) is a worldwide initiative to accelerate progress and efforts toward achieving the Sustainable Development Goals (SDGs) within the designated decade.	Rise of STEM for Sustainability: STEM education is increasingly incorporating sustainability topics to prepare students for careers in green industries.

(EU STEM Coalition, 2023; NRC, 2014; NSF, 2024; OECD, 2018; UN, 2015a, 1998; UNESCO, 2017; WEF, 2020)

The alignment between STEM education and SDGs is historical and impactful. For instance, SDG 4 (Quality Education) and SDG 13 (Climate Action) are directly supported through STEM's emphasis on innovation and sustainability. Over decades, this integration has fostered skills essential for addressing global challenges, highlighting STEM's significant contribution to sustainable societal progress.

Conclusion: STEM Education for a Sustainable Future

STEM education is pivotal in equipping the next generation with the skills and knowledge needed to address global challenges. By prioritizing inclusivity, gender equality, and sustainability, STEM education can drive innovative solutions, foster sustainable economic growth, and lay the foundation for a resilient and equitable future. However, persistent cultural stereotypes, a lack of role models, and gender-biased curricula continue to hinder equal participation. Overcoming these barriers is essential not only to empower women in STEM but also to enrich society with their valuable contributions. Promoting diversity and inclusion within STEM education is critical to unlocking its full potential for societal progress.

To achieve this vision, it is crucial to eliminate obstacles and build student resilience in sustainable STEM fields, align STEM curricula with the evolving demands of sustainability-focused careers, and implement effective teaching strategies that emphasize foundational STEM and sustainability concepts alongside systems thinking. Furthermore, fostering skills such as flexibility, creativity, teamwork, problem-solving, and communication, with a strong focus on sustainability, is essential. Continuous evaluation and adaptation of educational frameworks are necessary to ensure sustainability-driven learning for current and future generations. By advancing STEM education and embedding principles of sustainable development, we pave the way for a future that is innovative, inclusive, and capable of addressing the complexities of tomorrow’s world. Empowered by STEM, we are collectively shaping a sustainable and robust future for all.

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Education, science, and technology disciplines at all levels have never been more important, more exciting, or more crucial for its broader impacts on human society. The need for advanced technical skills is increasingly pressing to address cscentific issues, enhance the infrastructural built environment, grow food sources to feed an expanding planetary population, make new scientific discoveries, and interface synergistically with the arts, humanities, and social sciences.

Teachers/instructors/mentors/ professors need to be proficient in the best ways to convey knowledge and motivate the next generations of productive and engaged citizens of an increasingly diverse planet on which its human inhabitants must learn to confront and surmount increasingly difficult challenges to survival and prosperity. Students need to be focused on honing their learning skills and adapting to an ever-evolving global economy demanding always higher levels of technical proficiency. Students also need to be free to pursue any and all areas of interest without interference from cultural, political, ideological, or faith-imposed limitations. Policymakers need to provide the financial and human resources to fuel the engine of education, and they must create the maximum possible latitude for both those who teach and those who learn to pursue science, technology, engineering, and mathematics to their limits. This book contributes to addressing these needs and to suggesting potential solutions from multiple global perspectives. Adaptability of instructional methods, relevance of instructional content to students' lived experiences, and sensitivity to the mental and physical demands imposed on students must be hallmarks of education.

The book iincludes the following 8 chapters:
Chapter 1 - Technology Utilisation In Learning (A Case Study Senior High School 3 Simpang Hilir North Kayong Regency, West Kalimantan Province)
Chapter 2 - The Effectiveness of Using Quick Response (QR) Code in Indonesian Students' Elementary School Textbook Toward Their Learning Outcomes and Motivation in Learning English
Chapter 3 - Digital Teaching Material and Media Integrating Local Potential in Biology for Biotechnology Learning: ASystematic Literature Review
Chapter 4 - Students' Functional Thinking in Mathematical Problem-Solving: With and Without Scaffolding
Chapter 5 - Lighting the Way: Scaling the Microgrid Project to Promote STEM Learning in Rural Non-Privileged Communities
Chapter 6 - Challenges and Prospects of Cutting-Edge Technology in Education
Chapter 7 - 21st Century Skills: Student's Creative Thinking Skills Through STEAM Integrated Project Learning
Chapter 8 - Sustainable Development Through STEM Education

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