

Analysis of the Application of SDGs-Based STEM Learning in Improving Critical Thinking Abilities and Environmental Awareness

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Abstract

STEM learning plays a crucial role in achieving the Sustainable Development Goals (SDGs) by equipping individuals with the knowledge and skills needed to address global challenges such as climate change, clean energy, and technological innovation. Integrating STEM into education supports SDG 4, which focuses on quality education, while the application of STEM technology contributes to achieving other SDGs, including health, decent work, and infrastructure development. Therefore, STEM is essential for creating sustainable solutions that can enhance prosperity and quality of life worldwide. This research aims to investigate and analyze the extent to which SDG-based STEM integration has been implemented in learning and its correlation with the improvement of critical thinking skills and environmental awareness. The research is conducted as a survey involving 20 teachers and 60 students as respondents. Data collection was carried out through the distribution of questionnaires to analyze the needs related to the implementation of SDG-based STEM learning in enhancing critical thinking skills and environmental awareness. The analysis results indicate that the implementation of SDG-based STEM learning is still infrequent in schools, with limited knowledge among teachers and students regarding STEM and the SDGs. Additionally, students' critical thinking skills and environmental awareness remain low. This research concludes that implementing SDG-based STEM learning is essential for improving students' critical thinking skills and environmental awareness. Therefore, it is crucial to adopt SDG-based STEM learning to support the achievement of sustainable educational goals.

Keywords: STEM, SDGs, Critical Thinking Ability, Environmental Concern

INTRODUCTION

The Sustainable Development Goals (SDGs) were established by the United Nations as a universal call to action to tackle the world's most urgent challenges by 2030 (Anheier, 2007). These 17 interconnected goals serve as a comprehensive framework for fostering sustainable development across social, economic, and environmental dimensions. Key objectives include addressing climate change, promoting health and well-being, ensuring access to clean energy, and advancing technological innovation, all of which are crucial for the overall prosperity of societies worldwide (Colonnelli, & Prem, 2022). The SDGs recognize that achieving sustainable development requires transformative change across sectors, including education, which plays a vital role in equipping individuals and communities with the knowledge and skills needed to drive this change.

In recent years, Science, Technology, Engineering, and Mathematics (STEM) education has gained prominence as an essential approach for advancing sustainable development (Williams, 1976). STEM is seen as more than a collection of disciplines; it is a holistic educational approach that emphasizes critical thinking, problem-solving, and real-world application of knowledge. By

fostering scientific literacy, technological proficiency, engineering design thinking, and mathematical reasoning, STEM education prepares learners to navigate complex global issues effectively. The interdisciplinary nature of STEM is particularly aligned with the SDGs, as it enables learners to approach challenges such as climate change, health crises, and technological innovation with integrated, multifaceted solutions.

One of the central goals of the SDGs is Goal 4, which aims to ensure inclusive and equitable quality education for all. Integrating STEM education into the learning process directly supports this objective by providing learners with not just foundational knowledge but also advanced competencies necessary for a rapidly evolving world. Quality STEM education fosters the development of skills that are critical for addressing global issues, including digital literacy, analytical thinking, and creativity. Moreover, the emphasis on practical application in STEM aligns closely with the need to develop sustainable solutions that can be scaled and adapted to different local and global contexts, contributing to the achievement of other SDGs such as health (Goal 3), decent work and economic growth (Goal 8), and industry, innovation, and infrastructure (Goal 9).

Despite the recognized importance of STEM in advancing the SDGs, the implementation of SDG-based STEM learning in educational settings is not yet widespread or fully understood. While there is a growing awareness of the potential of STEM to drive sustainable development, there is a need to explore how these concepts are integrated into school curricula and teaching practices. This gap in implementation is not only a matter of curriculum content but also of pedagogical approaches and teacher preparedness. A deeper understanding of how STEM education can be effectively leveraged to support the SDGs is critical for ensuring that students are equipped with the skills needed to contribute to sustainable development and to tackle complex issues such as environmental degradation and technological change.

The current study seeks to investigate the extent to which SDG-based STEM integration has been implemented in educational practice and to analyze its relationship with students' critical thinking skills and environmental awareness. Critical thinking is an essential skill for the 21st century, enabling students to analyze information, evaluate different perspectives, and solve problems effectively. Similarly, environmental awareness is a key aspect of sustainable development, as it fosters a deeper understanding of ecological systems and encourages responsible actions towards the environment. By examining the implementation of SDG-based STEM learning, this research aims to uncover the potential benefits of this approach in enhancing critical thinking and environmental awareness among students, thereby supporting the achievement of sustainable education goals.

Ultimately, this study contributes to the growing body of literature on the role of education in sustainable development and the specific impact of STEM learning on student outcomes. By providing insights into how SDG-based STEM education can be effectively integrated into school curricula and the ways it influences student competencies, the research aims to offer practical recommendations for educators, policymakers, and stakeholders. Through the development of effective STEM-based strategies aligned with SDG objectives, there is an opportunity to advance not only the quality of education but also the broader goals of sustainable development, ensuring that learners are well-prepared to contribute positively to society and the global community.

METHODS

The methodology employed in this research is based on a survey approach, which allows for a systematic collection of data regarding the perceptions and experiences of both teachers and students concerning SDG-based STEM education. A total of 80 respondents participated in the study, comprising 20 teachers and 60 students, all of whom were selected to represent a diverse range of backgrounds and experiences within their educational context (Stephenson, 2022). This mix of respondents was chosen to ensure a balanced perspective on the current state of STEM learning in relation to the Sustainable Development Goals (SDGs), as well as to gauge the level of awareness and attitudes towards the integration of these concepts into the curriculum. The survey method was particularly effective for capturing the subjective viewpoints of teachers and students, providing insights into their knowledge, challenges faced, and the perceived benefits of implementing SDG-oriented STEM education.

The data collection process was conducted using a structured questionnaire designed to analyze the needs, challenges, and gaps associated with implementing SDG-based STEM learning. The questionnaire was carefully developed to include both quantitative and qualitative questions, allowing for a comprehensive understanding of the respondents' experiences. The quantitative items focused on assessing the familiarity and understanding of STEM concepts and their relevance to the SDGs, as well as measuring the frequency and extent of STEM-based activities in their educational settings. Meanwhile, the qualitative components sought to capture more nuanced insights into the practical challenges faced by educators in integrating STEM into their teaching, as well as the perceptions of students regarding how STEM learning can improve their critical thinking skills and environmental awareness. This mixed-method approach was adopted to ensure that the data collected would provide a holistic view of the current implementation status of SDG-based STEM learning and highlight areas for potential improvement and development.

RESULTS

The findings from the survey indicate that the integration of SDG-based STEM learning in school curricula remains minimal, suggesting a significant gap between educational policy and classroom practice. While STEM and SDGs have been widely recognized as vital components of modern education, their combined application is rarely seen in daily teaching activities. Teachers often face challenges in finding practical ways to integrate STEM concepts in relation to SDGs within their lesson plans. Additionally, institutional barriers such as lack of resources, insufficient training, and limited curriculum time contribute to the scarcity of such integrative approaches. Consequently, the majority of teachers reported that they seldom incorporate SDG-based STEM activities in their classrooms, despite recognizing the importance of such interdisciplinary teaching for holistic student development.

Further analysis of the survey data reveals a concerning lack of knowledge and understanding among both teachers and students regarding fundamental STEM concepts and their connections to the SDGs. Most teachers indicated only a basic familiarity with STEM and SDGs, with many finding it challenging to translate these concepts into classroom activities that effectively foster problem-solving, innovation, and real-world application. This lack of exposure directly affects the students' grasp of STEM and SDGs, as evidenced by the responses indicating limited awareness and

understanding of how STEM learning can address global challenges. Consequently, this knowledge gap prevents both teachers and students from engaging fully with the critical skills and sustainable thinking that STEM education seeks to promote.

The results also point to a notable deficiency in the development of critical thinking skills and environmental awareness among students, both of which are key competencies for the 21st century and integral to achieving the SDGs. Students demonstrated limited ability to engage in critical analysis, problem-solving, and decision-making in contexts that require an understanding of environmental issues and sustainable practices. The lack of focus on STEM-related projects or interdisciplinary activities in the current curriculum further restricts students' opportunities to develop these essential skills. This finding underscores the need for comprehensive strategies to integrate SDG-based STEM learning into education more effectively, which would not only improve the knowledge and application of STEM concepts but also enhance students' capacity for critical thinking and their understanding of environmental stewardship. Overall, the survey results emphasize the urgent requirement for a structured and well-supported approach to SDG-based STEM education, fostering both the skillsets and mindsets needed for students to contribute to sustainable development in meaningful ways.

DISCUSSION

The limited implementation of SDG-based STEM education, as revealed by the study's findings, presents a substantial opportunity to enhance current educational practices to better align with sustainable development goals. The gap in the incorporation of SDG-related themes into STEM education suggests that a transformative approach is needed to bring these critical concepts into mainstream teaching and learning. The disconnect between educational objectives and classroom practices not only impedes the realization of the full benefits of STEM education but also hinders the broader goal of equipping students with the skills needed to address global challenges. To address this gap, it is crucial to consider how SDG-based STEM learning can be integrated more systematically into school curricula, promoting an interdisciplinary approach that fosters critical thinking and problem-solving.

One of the central issues identified is the lack of awareness and understanding of both STEM concepts and the SDGs among teachers and students. Teachers play a pivotal role in shaping how STEM and SDG concepts are presented and understood by students, yet the findings suggest that many educators are not adequately prepared to integrate these themes effectively. The reasons for this include insufficient professional development, limited exposure to current STEM-related global issues, and a lack of access to relevant teaching materials. Consequently, there is a need for targeted training programs to equip teachers with the necessary skills, knowledge, and confidence to deliver STEM education through the lens of the SDGs. Such professional development opportunities should focus not only on STEM content but also on pedagogical strategies for interdisciplinary teaching, allowing educators to make meaningful connections between STEM and the broader context of sustainable development.

For students, the lack of exposure to SDG-based STEM learning has resulted in limited development of critical thinking skills and environmental awareness, both of which are crucial for engaging with global challenges. The current educational approaches may not adequately stimulate students' abilities to analyze, evaluate, and apply knowledge in practical and relevant ways (Deutsch, 1963). By integrating SDG themes into STEM learning, students can develop a deeper understanding of real-world issues, enhancing their capacity to think critically about complex

problems. Moreover, hands-on STEM activities related to SDG topics, such as renewable energy, clean water, and sustainable cities, can provide students with the experiential learning opportunities necessary to foster a sense of environmental stewardship and social responsibility, empowering them to become active contributors to sustainable solutions.

The implementation of SDG-based STEM education also necessitates curriculum development that aligns with both national educational standards and global sustainability goals. Currently, most curricula do not explicitly connect STEM learning with SDGs, leading to missed opportunities for interdisciplinary learning and application. A well-designed curriculum that integrates STEM concepts with SDG themes can serve as a roadmap for educators, guiding them on how to infuse sustainable development into their teaching practices. This approach would require the development of learning objectives that focus on skill development, such as critical thinking, collaboration, and innovation, as well as the inclusion of relevant, context-based content that reflects the local and global challenges addressed by the SDGs. Such a curriculum should be dynamic and adaptable, allowing for flexibility in how teachers approach different topics and ensuring that students receive a holistic and comprehensive understanding of the interconnectedness between STEM and sustainability.

Beyond curriculum changes, the role of resources and support in implementing SDG-based STEM education is critical. Schools and educators need access to high-quality teaching materials, tools, and resources that are specifically designed to address the intersection of STEM and SDGs. This includes lesson plans, digital resources, case studies, and project-based learning opportunities that are aligned with the themes of sustainable development. Furthermore, partnerships between schools, communities, and organizations can be leveraged to provide practical experiences for students, such as fieldwork, community projects, and collaborations with local businesses or NGOs working towards sustainable solutions. These experiences not only enrich the learning process but also demonstrate to students the real-world relevance and impact of SDG-based STEM learning.

In conclusion, the findings of this study underscore the urgent need for a strategic and comprehensive approach to integrating SDG-based STEM education into mainstream schooling. By providing professional development for teachers, developing a curriculum that aligns STEM learning with sustainable development goals, and ensuring access to appropriate resources and support, it is possible to enhance both the educational experience and the outcomes for students. Such efforts will not only improve students' critical thinking skills and environmental awareness but also prepare them to be proactive, informed, and responsible global citizens who are equipped to contribute meaningfully to a sustainable future. These changes have the potential to significantly contribute to the achievement of the SDGs by fostering a generation of learners who are both knowledgeable and passionate about creating a better world through STEM-driven innovation and sustainable practices.

CONCLUSION

The study concludes that the integration of SDG-based STEM learning into educational systems is pivotal for nurturing critical thinking skills and environmental awareness among students. This approach goes beyond traditional content delivery, focusing on equipping students with the competencies required to understand and address complex global challenges. By aligning STEM education with the Sustainable Development Goals (SDGs), learners are exposed to interdisciplinary themes that connect science, technology, engineering, and mathematics with real-world issues such as climate change, clean energy, and sustainable development. This alignment not

only enriches students' academic experience but also encourages a mindset geared toward problem-solving, innovation, and responsible citizenship. The findings underscore the transformative potential of SDG-based STEM learning in fostering a more holistic and socially relevant educational experience, which ultimately contributes to the broader goal of sustainable development.

To achieve these sustainable educational goals effectively, it is crucial to develop and implement comprehensive strategies that incorporate SDG-based STEM learning into the school curriculum. This involves creating a well-rounded framework that supports teachers through training and professional development, provides access to relevant resources and materials, and incorporates hands-on, experiential learning opportunities. Additionally, establishing policies that promote the interdisciplinary integration of STEM and SDG themes is essential for a cohesive educational approach. Further research is recommended to identify the most effective models and practices for embedding SDG-based STEM learning into educational systems, as well as to assess the long-term impacts on students' critical thinking abilities, environmental awareness, and overall learning outcomes. Understanding the influence of these strategies on both individual students and the broader community will help refine approaches to STEM education that support the achievement of sustainable development goals at local, national, and global levels.

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