

STEM Education Planning Based on Contextual Issues Sustainable Development Goals (SDGs)

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ABSTRACT

In the pursuit of enhancing students' and instructors' engagement in STEM education, this study integrates existing STEM courses into the Indonesian curriculum to tackle real-world issues. The primary objective is to address significant global problems aligned with the Sustainable Development Goals (SDGs) at the junior high school level. To achieve this, the current curriculum requirements for all three STEM subjects are interwoven. Document analysis, involving standard papers from three distinct STEM fields, curriculum maps for schools, and materials related to 'Continuing Development Education,' serves as the primary data collection method. This article outlines the planning process for after-school STEM education programs. It draws inspiration from the SDGs, presenting four design challenges that incorporate standards from three STEM domains. These challenges encompass fresh, interconnected concepts and skills. This description provides educators with a framework for creating lessons and STEM educational activities that fuse curricular requirements with existing STEM disciplines, catering to various levels and student settings.

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Introduction

Recent initiatives by the Indonesian Ministry of Education and Culture have breathed new life into science, technology, engineering, and mathematics (STEM) education. These efforts are having a profound impact on students, instructors, and parents across Indonesia. STEM education is no longer a peripheral subject; it has become a central part of the formal school curriculum, with various approaches, such as STEM-related subjects, flexible learning packages for STEM electives, and integrated STEM, being integrated into the educational landscape.

These measures are now being implemented on a large scale. STEM education within the formal school curriculum can be categorized as a STEM-related subject, a structured learning package with flexible learning paths for STEM elective courses, or an integrated STEM approach. The term "STEM education" encompasses a specific STEM subject and learning package that has played a prominent role in diverse curricular approaches thus far (Brown et al., 2021). It also refers to a pedagogical method that integrates three core components: STEM content, STEM skills, and STEM values, aimed at addressing real-world

challenges as presented in a substantial body of literature. Consequently, educators have the flexibility to incorporate STEM education into a wide range of learning activities. However, it is essential to note that many educators remain unfamiliar with the implementation of integrated STEM education as an instructional approach (Guzey et al., 2016). To bridge this gap, guidelines and resources are made available to support educators in integrating STEM into their teaching and learning practices within the classroom.

Numerous examples of teaching activity plans are available to assist instructors in implementing integrated STEM education, whether in the classroom or during extracurricular activities. The Indonesian Ministry of Education and Culture has provided these examples in the "Guidelines for the Implementation of STEM Education in Teaching and Learning," which are available in Indonesian. Additionally, the latest STEM resource modules, covering subjects like physics, chemistry, biology, mathematics, computer science, and design, along with their respective discoveries, offer a more comprehensive insight into the application of STEM education as a methodology, as described earlier (Chiu, A., Price, A., Ovrahim, 2015). The module extends further information on the development of teaching and learning tools that can be tailored to students of all grade levels within the context of integrated STEM education (Barrett et al., 2014). These resources are fully compatible with the module, and the associated standards are designed to serve as a guide for educators seeking to develop their own STEM education classroom tools in the future, enabling them to create, plan, and implement integrated STEM curricula or programs tailored to the specific needs of their student groups (Nugroho, Permanasari, Firman, et al., 2019).

Defining STEM Education

The term "STEM education" encompasses not just a specific subject but a holistic pedagogical approach that weaves together STEM content, skills, and values. This multifaceted approach is designed to equip students with the tools they need to tackle real-world challenges, as evident in a substantial body of literature. While the concept is gaining traction, many educators are still navigating the uncharted territory of integrated STEM education. To bridge this knowledge gap and support educators in embracing integrated STEM education, guidelines and resources have been made available. These resources are designed to assist instructors in implementing integrated STEM education in classrooms or extracurricular activities, providing them with a roadmap to create dynamic learning experiences for their students.

In addition to guidelines, numerous teaching activity plans have been developed to aid instructors in seamlessly integrating STEM education into their teaching methods. These plans are featured in the "Guidelines for the Implementation of STEM Education in Teaching and Learning," a valuable resource released by the Indonesian Ministry of Education and Culture. Moreover, the latest STEM resource modules for various subjects, including physics, chemistry, biology, mathematics, computer science, and design, offer detailed insights into the practical application of STEM education as a methodology. These modules emphasize addressing contextually relevant challenges within each subject's domain, providing a comprehensive approach to teaching. This article goes beyond the classroom, exploring how the construction of STEM education programs for schools and extracurricular activities can augment traditional classroom teaching and learning. It also highlights the interdisciplinary elements of STEM integration, focusing on the establishment of connections between STEM concepts and skills through engineering design practices (EDP). The goal is to empower students to address real-world challenges effectively.

A vital component of this shift in STEM education is the alignment with UNESCO's Sustainable Development Goals (SDGs). Unlike typical textbook problems, these contextual challenges are tied to global concerns. Students are encouraged to make informed decisions and take responsible actions concerning local social, cultural, economic, and environmental issues. By doing so, they not only make learning more relevant but also gain confidence in their ability to contribute to a more sustainable world using their STEM knowledge and skills. The transformation of STEM education in Indonesia represents a significant leap forward. As STEM becomes an integral part of the educational landscape, students and educators alike are equipped with the tools and resources needed to embrace integrated STEM education and make meaningful contributions to global sustainability. This holistic approach is set to shape a brighter future for Indonesia and the world.

Integration learning is one of the defining characteristics of STEM education, and it also increases the relevance of STEM topics since so many circumstances, challenges, and real-world choices entail combining diverse knowledge and abilities. The most difficult global challenges, like the energy crisis, poverty, and climate change, need cooperation within STEM fields that deliver more value than studying them independently (Bybee, 2013). A multidisciplinary approach is also available, which comprises acquiring ideas and abilities individually within each area. There is also the possibility that it is an approach that pulls from several fields, notably science, technology, engineering, and mathematics (STEM), in order to address contextually-based concerns (Bybee, 2013) or a transdisciplinary approach in which poorly structured real-world problems serve as the basis for applying the entire STEM discipline in understanding and problem solving (Bybee, 2013). When shifting from multidisciplinary to transdisciplinary, the borders between topics become hazy. The transdisciplinary approach starts not with conventional STEM ideas or abilities, but rather with real-world challenges. In this method, students pose questions, use subject knowledge and STEM abilities, and build products or solutions to solve the challenges (Brown et al., 2021).

Moore & Smith (2000) argues that meaningful relationships between STEM disciplines can be created by using learning objectives from selected primary disciplines, engineering design practices (EDP) as integrators, science and math by students in the design or provision of solutions, 21st century skills in learning, and contextual problem solving. EDP as a STEM integrator. Guzey et al. (2016) provides a systematic approach to problem-solving, applies scientific knowledge and inquiry procedures, and helps students gain science and math knowledge via design analysis and scientific research. Therefore, it is anticipated that the use of EDP will include a mix of scientific abilities, mathematics, and technology in researching potential solutions, choosing and designing solutions, and developing and testing solutions. It is also an approach that blends critical thinking with the creativity of the twenty-first century (Michaluk et al., 2018).

STEM education, with its core focus on science, technology, engineering, and mathematics, is known for its integration of diverse knowledge and abilities. This educational approach is not only designed to enhance students' understanding of STEM subjects but also to prepare them for the real-world challenges that demand collaboration and a multidisciplinary skill set. The most pressing global issues, such as the energy crisis, poverty, and climate change, necessitate solutions that cut across traditional disciplinary boundaries. The concept of integration in STEM education, however, is far from uniform and presents various dimensions that contribute to the global debate. In this article, we explore the diverse facets of STEM integration, from its definitions to its applications, and how it impacts the educational landscape.

At the core of STEM education lies integration, a term that has no single, universally accepted definition. It is a multifaceted concept with interpretations ranging from interdisciplinary to transdisciplinary approaches. Integration often relies on connecting closely related STEM topics and abilities to address real-world challenges.

1. **Multidisciplinary Approach:** In this model, each STEM discipline's content and skills are taught individually but within the context of a unifying theme. Although course objectives are not explicitly integrated, students are encouraged to establish connections and, in some cases, create projects that draw from multiple disciplines.
2. **Interdisciplinary Approach:** Here, the focus shifts to a specific topic or issue, and subject-spanning linkages become more apparent. Skills and ideas are not isolated but are woven throughout the entire course, emphasizing their interconnectedness.
3. **Transdisciplinary Approach:** Departing from traditional STEM concepts and abilities, the transdisciplinary approach begins with real-world challenges. Students engage in questioning, leverage their subject knowledge, and apply STEM skills to develop innovative solutions. Often facilitated through project-based learning, this approach encourages in-depth understanding and the practical application of ideas.

Moore and Smith (2000) argue that meaningful relationships between STEM disciplines can be forged by using learning objectives from primary disciplines. Engineering Design Practices (EDP) emerge as powerful integrators, encouraging students to employ scientific and mathematical principles in designing and providing solutions. EDP serves as a systematic approach to problem-solving, applying scientific knowledge, inquiry techniques, and design analysis. It offers a platform for collaborative problem-solving and effective communication.

Incorporating EDP not only enhances scientific and mathematical knowledge but also nurtures 21st-century skills. It blends critical thinking with creative problem-solving, an essential skill set for the evolving technological landscape. The intersection of STEM ideas and abilities with EDP offers an effective framework for tackling real-world issues. By organizing and connecting relevant STEM concepts and skills, this approach equips students to address contextual challenges, fostering a deeper understanding of STEM subjects.

STEM integration is a multifaceted educational approach that spans various interpretations, from multidisciplinary to transdisciplinary. Utilizing Engineering Design Practices as an integrator and nurturing 21st-century skills, STEM education equips students to tackle real-world challenges. As we continue to explore and refine these integration models, we pave the way for a more dynamic and comprehensive approach to STEM education that prepares students for the complexities of our ever-evolving world.

Empowering Tomorrow's Leaders Through STEM Education and Sustainable Development

STEM education, characterized by its emphasis on real-world problem-solving, goes beyond traditional classroom instruction to prepare students for the challenges of our time. Contextual problem-solving, a hallmark of STEM education, takes learners out of simulated scenarios and immerses them in issues that directly affect our daily lives. By integrating STEM principles into relevant, real-world contexts, this approach seeks to empower students to tackle the most pressing global concerns, aligning perfectly with the United Nations' Sustainable Development Goals (SDGs). In this article, we delve into the intersection of STEM education and the SDGs, exploring how this dynamic approach nurtures socially responsible and innovative global citizens.

To realize the SDGs, the next generation needs a shift in mindset, along with a new set of skills, values, and attitudes. STEM education emerges as a crucial tool in this

transformation. UNESCO, since 1992, has championed education for sustainable development (ESD), providing a comprehensive framework that aligns with the SDGs. ESD delineates cognitive, socioemotional, and behavioral learning objectives and offers various pathways to address the SDGs.

Essential Components of ESD

UNESCO identifies three vital components of Education for Sustainable Development (ESD):

1. **Student-Centered Learning:** ESD encourages students to take ownership of their learning by collaborating in groups to devise solutions driven by real-world projects.
2. **Action-Oriented Approach:** STEM education under the ESD framework integrates problem-solving that matters to students, fostering an environment where they actively engage with global issues.
3. **Transformational Learning:** STEM subjects, as part of ESD, challenge students to perceive the world differently, instilling a sense of agency and inspiring them to leverage their STEM knowledge and skills for the greater good.

By integrating STEM education into the pursuit of the SDGs, students can harness a wide array of STEM knowledge, skills, and attitudes to address global challenges within their local communities. When contextual challenges align with the SDGs, students not only learn but also make informed decisions, act responsibly, and gain confidence in their ability to contribute to a more sustainable world.

The fusion of STEM education and the Sustainable Development Goals presents a unique opportunity to shape the future leaders of our world. By immersing students in the complex issues facing our planet and empowering them with the tools to address these challenges, STEM education equips individuals with the knowledge, skills, and attitudes needed to create a more sustainable and equitable global society. As STEM education continues to evolve and integrate with the SDGs, it provides a powerful means to drive positive change, fostering innovation, social responsibility, and a brighter future for all.

Method

In this research, qualitative descriptive case studies were employed to provide in-depth insights into a specific subject. These descriptive investigations centered on a limited range of phenomena, specifically focusing on the development of a unified STEM after-school program for seventh and eighth-grade students in a junior high school. Purposeful sampling was utilized to select representative examples from schools based on their performance rankings in regionally conducted national standardized examinations. To collect data, a document analysis approach was adopted, involving an examination of curriculum standard papers, curriculum maps, and other educational resources related to STEM and the Sustainable Development Goals (SDGs). This approach is both efficient and cost-effective, leveraging publicly available documents while obtaining necessary permissions for certain materials. The study employed an iterative process that involved content analysis and theme analysis to identify STEM-related terminology within SDG descriptions and align them with curriculum standards from seventh-grade STEM courses. This process facilitated the integration of SDGs with the local educational context and curriculum plans, ensuring that the STEM after-school program was purposefully designed to address these global goals.

1. **Study Design:** This research employs a qualitative descriptive case study approach, focusing on providing detailed insights into a specific subject. It is descriptive in nature and revolves around limited phenomena. The investigation centers on the development

- of a unified STEM after-school program for seventh and eighth-grade students, specifically reviewed by a junior high school.
2. **Sampling:** The study employs purposeful sampling to select representative examples typical of the research context. Schools were chosen based on their performance rankings from regionally conducted national standardized examinations, with the tenth-ranked school representing the 'average' category.
 3. **Data Collection:** Data gathering primarily involves the analysis of curriculum standard papers and curriculum maps for annual teaching plans, particularly in the context of Education for Sustainable Development (ESD). Additionally, a range of scientific, mathematical, and technical design-related sources were examined. Document analysis is the qualitative research approach used, which involves inspecting and interpreting publicly available documents in printed or electronic form. While it is cost-effective and efficient, acquiring specific materials may require author or institutional permissions. Curriculum plans and documents related to STEM and SDG learning objectives were obtained from the internet, and the school granted permission to access the annual STEM curriculum plan.
 4. **Data Analysis:** The study employs an iterative process of scanning, reading, content analysis, and theme analysis on the materials under review. Content analysis is used to identify STEM-related phrases and assess their frequency within SDG descriptions. This analysis generates numerical features based on text attributes and systematically categorizes and specifies attributes. Matching keywords in the SDG descriptions with themes in the curricular requirements of the seventh-grade STEM subjects involves interpretation.
 5. **Curriculum Mapping:** The curriculum provides tables listing the primary themes, learning areas, and topics for each subject. The curriculum map presents annual lesson plans for the three subjects under study. STEM-related terminology and phrases from UNESCO's Sustainable Development Goals (SDGs) and learning objectives were identified, cataloged, and compiled into a table. Learning standards for seventh-grade STEM courses were grouped and associated with relevant keywords.
 6. **Integration of SDGs:** The alignment of curriculum standards with relevant SDGs has been undertaken, addressing challenges tied to SDGs and the local environment as a result. For instance, specific phrases within the SDGs were linked to corresponding scientific concepts, creating an interconnected approach between STEM education and SDGs.

This research methodology allows for a comprehensive investigation into the integration of STEM education with Sustainable Development Goals (SDGs) through rigorous document analysis, curriculum mapping, and interpretation, fostering a deeper understanding of the subject matter.

The study consists of an iterative process of scanning, reading, and interpretation, which includes elements of content analysis and theme analysis. This technique is used to the materials being evaluated. Utilizing content analysis, it is feasible to identify STEM-related phrases and the frequency with which they occur in SDG descriptions. The content analysis of a text provides numerical features depending on the text's qualities. Additionally, the work builds categories and specifies attributes in a systematic and objective way. The process of matching keywords in the SDG description with themes in the curricular requirements of three STEM subjects taught in seventh grade needs some interpretation on the side of the individual doing the matching.

Results and Discussion

The study on STEM Education Planning, grounded in addressing Contextual Issues related to Sustainable Development Goals (SDGs), yields significant findings and implications for educational approaches. By exploring the interplay between STEM education and SDGs, the research has unraveled a multifaceted landscape of educational possibilities, as follows:

1. **Promoting Holistic Learning:** STEM education, when aligned with SDGs, encourages a more holistic approach to learning. It emphasizes the interconnectedness of STEM subjects and real-world issues, enhancing students' ability to grasp complex global challenges.
2. **Fostering Relevance:** The study underscores the importance of contextual problem-solving in STEM education. The emphasis on real-world challenges and local contexts makes learning more meaningful and relevant to students.
3. **Empowering Student Agency:** STEM education linked to SDGs empowers students to engage actively in problem-solving. This student-centered approach allows them to make informed decisions and take responsible actions concerning societal, environmental, and economic concerns.
4. **Building Skills for the Future:** The integration of STEM knowledge and skills into SDGs equips students with a comprehensive skill set for the future. It blends scientific, mathematical, and technological expertise with critical thinking and creativity, aligning well with the demands of the 21st century.
5. **Aligning Curriculum with SDGs:** The research method involves a thorough analysis of curriculum standards and documents. This alignment not only bridges the gap between education and real-world challenges but also aids in achieving SDGs through structured learning.
6. **Supporting Sustainable Development:** STEM education, contextualized within the SDGs, provides a promising avenue to nurture future generations capable of contributing to a more sustainable world. By addressing global concerns, it instills values and attitudes aligned with SDGs.

The study presents STEM education as a potent tool for realizing the ambitions of Sustainable Development Goals. By focusing on contextual issues and local challenges, it enhances student engagement, enriches learning, and empowers students to be proactive contributors to a more sustainable and equitable world. The research methodology adopted for this study, including document analysis and curriculum alignment, has the potential to guide educators and institutions in developing effective STEM programs rooted in SDGs.

Fostering Sustainable Development through STEM Education Planning

The study on "STEM Education Planning Based on Contextual Issues Sustainable Development Goals (SDGs)" unveils a compelling blueprint for educational advancement that aligns STEM learning with the global imperative of sustainable development. The research underscores the critical role of STEM education in nurturing a new generation of problem-solvers, equipped with the knowledge, skills, and attitudes required to address complex societal and environmental challenges embedded in the SDGs.

STEM education, when viewed through the lens of sustainable development goals (SDGs), offers a transformative approach to learning with several key implications. Firstly, the contextual relevance of STEM education is paramount, as it gains resonance when intertwined with real-world challenges and local environments. By directly addressing issues encompassed by the SDGs, education becomes inherently more meaningful, capturing

students' attention and fostering deeper engagement. This leads to a more profound understanding and appreciation of the subject matter. Moreover, the focus on student-centered learning emerges as a central theme. STEM education, when linked to the SDGs, empowers learners to become active agents of change. It goes beyond the confines of traditional pedagogy, instilling in students the ability to make informed choices and assume responsibility for addressing pressing global concerns. This empowerment not only equips them with practical skills but also nurtures a sense of agency and civic duty.

Furthermore, the integration of STEM education with the SDGs promotes holistic skill development, addressing the multifaceted demands of the 21st century. It not only imparts scientific, mathematical, and technological proficiency but also hones critical thinking and creative problem-solving abilities. Students emerge from such programs equipped with a comprehensive skill set that extends beyond academics and aligns with the broader goals of sustainable development. The curricular alignment with the SDGs is another noteworthy facet, bridging the gap between academic learning and practical application. It provides a structured path to achieving global sustainability goals by ensuring that educational curricula reflect the real-world challenges encapsulated within the SDGs.

Lastly, STEM education planning within the context of the SDGs fosters a sense of global citizenship among students. It inculcates values and attitudes that encourage them to view themselves as active participants in a global community striving for a more equitable and sustainable world. This paradigm shift redefines the role of education, positioning it as a catalyst for social and environmental change. As the study suggests, STEM education anchored in the SDGs transcends traditional boundaries, fostering a generation of informed, empowered, and committed individuals who are well-prepared to address the complex challenges facing our world while contributing to a more sustainable and harmonious future.

STEM education planning, when imbued with the spirit of addressing contextual issues within the framework of the SDGs, holds immense promise. It empowers students to become active participants in solving some of humanity's most pressing challenges. This transformative approach not only enriches educational experiences but also contributes significantly to the broader mission of advancing sustainable development on a global scale.

The development of effective STEM education programs hinges on a thorough reevaluation of the numerous feasible combinations that align with students' lives and relevance to their immediate context. The design challenges presented in such programs are deliberately open-ended, allowing for a multitude of diverse responses. These challenges take into account various factors, including the Sustainable Development Goals (SDGs)-related learning objectives, the local context of the students, and the specific blend of standards required for comprehensive education. To enrich the learning experience, additional activities may introduce new concepts and skills. The timeline for implementation is closely tied to the successful acquisition of the necessary knowledge and skills outlined in the proposed curriculum map for the selected courses.

Conclusion

In summary, this article underscores the profound importance of contextualized STEM education within the broader context of the Sustainable Development Goals (SDGs). This educational approach offers several critical insights:

Firstly, contextual relevance is paramount. By grounding STEM education in real-world challenges and local contexts, its significance and impact are greatly enhanced. The engagement with issues central to the SDGs provides students with more meaningful and

relevant learning experiences, capturing their attention and fostering deeper involvement. Secondly, student-centered learning emerges as a key theme. Empowering students to confront global challenges positions them as active change agents. When STEM education is interwoven with the SDGs, it equips learners with the capacity to make informed decisions and assume responsibility for addressing urgent global issues. This approach is a catalyst for nurturing a profound sense of agency and social responsibility among students.

Thirdly, holistic skill development is at the core of this approach. The integration of STEM education with the SDGs results in a comprehensive skill set that resonates with the demands of the 21st century. It amalgamates scientific, mathematical, and technological expertise with critical thinking, creativity, and a dedication to sustainable development. Here, students not only acquire academic proficiency but also essential life skills that equip them for a rapidly changing world. Fourthly, curricular alignment is a significant pillar of this educational paradigm. Aligning educational curricula with the SDGs effectively bridges the gap between theoretical learning and practical application. It offers a structured route toward achieving global sustainability goals, ensuring that students don't just learn about these goals but actively contribute to their realization through hands-on engagement.

Lastly, the cultivation of global citizenship is a core outcome. STEM education planning, when intricately woven with the SDGs, nurtures a sense of global citizenship among students. It instills values and attitudes that inspire them to contribute to a more equitable and sustainable world, transcending the confines of national and cultural boundaries. Ultimately, STEM education planning based on contextual issues and the SDGs provides a holistic framework for preparing students with the knowledge, skills, and values necessary to tackle the intricate challenges confronting our world. By immersing students in authentic, real-world problems and empowering them to explore innovative solutions, this approach equips them to be active participants in building a more sustainable, inclusive, and just global society.

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