MATHEMATICS EDUCATION FOR SUSTAINABLE DEVELOPMENT: EXPLORING INTERDISCIPLINARY APPROACHES TO PROBLEM-SOLVING IN NIGERIA

BY

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Abstract

This paper explores the role of mathematics education in achieving sustainable development in Nigeria, with a focus on interdisciplinary approaches to problem-solving. Mathematics is a subject that has application in different disciplines in science and other fields of studies. Mathematics education on the other hand is the process of teaching and learning of mathematics, the knowledge of which is needed to address the country's development challenges. Through a review of literature, we demonstrate how mathematics can be applied to real-world problems in areas such as healthcare and agriculture. We also highlight the need for collaboration between mathematicians, scientists, and practitioners from other fields to develop innovative solutions. Our findings emphasize the importance of interdisciplinary mathematics education in preparing students to tackle complex problems and promote sustainable development in Nigeria.

Keywords: Mathematics education, Sustainable Development, Interdisciplinary Approaches, Problem-Solving.

Introduction

The relevance of mathematics in various facets of life cannot be overlooked as its application cuts across all fields of studies (Abari & Durodola, 2021) . Be it arts, social sciences, science and technology, medicine and so on. It provides carreer opportunities in science, engineering, data analysis, economics, actuarial science, computer and programming. It paves way for economic growth and development in innovation and enterpreneurship, economic modeling, resource allocation and management. Mathematics particularly improves cognitive abilities of an individual, enhances problem-solving skills, increases confidence and better decision making of an individual. According to Park, Brombacher & Brocardo (2021), Mathematics forms the fundamental part of human thought that provides effective ways of building mental discipline and encourages logical reasoning. That is why all hands must be on deck to ensure that mathematics education thrives in this technology driven society. Mathematics Education according to De Corte & Verschaffel (2001), is the process of teaching and learning mathematics, with a focus on understanding, problem-solving, and the construction of mathematical knowledge and cognitive skills. It involves designing effective teaching environment and creating innovative assessment methods aligned with the goals of mathematics education. The Sustainable Development Goals (SDGs) adopted by the United Nations in 2015 underscore the imperative of harnessing mathematics education to address pressing global challenges.

Globally, there is a growing recognition of the need to integrate mathematics with real-world applications and interdisciplinary approaches. The Organisation for Economic Co-operation and Development (OECD's) Programme for International Student Assessment (PISA) emphasizes the importance of problem-solving and critical thinking in mathematics education. In Nigeria, mathematics education faces significant challenges, including: Poor student performance in mathematics, limited qualified mathematics teachers, inadequate resources and infrastructure, disconnect between mathematics education and real-world applications(Adeyemo,2017; Ogunniyi, 2014 and Akpotu, 2019). Nigeria's developmental challenges, such as Poverty and inequality, climate change and environmental degradation, healthcare disparities, economic instability and insecurity, require innovative solutions that leverage mathematical education (Agboola 2021). Mathematics education for sustainable development is a multifaceted and interdisciplinary field that draws on diverse perspectives and expertise. Interdisciplinary

mathematics combines mathematical concepts and methods to solve problems, understand complex systems and address real-world challenges. The promotion of integrated or interdisciplinary approaches to mathematics and science learning has been characterized by enquiry-based processes that reflect the way these disciplines contribute to problem solving in real-world contexts (Tytler et al.,2022). There is also increasing interest in the potential of interdisciplinary approaches that integrate mathematics learning with learning in other disciplines and in particular in the context of Science, Technology, Engineering and Mathematics (STEM) (Doig et al., 2019; Maass et al., 2019)

Mathematics Education and Sustainable Development

Giving equal opportunity to quality education for all children is an urgent call for global sustainable development. Mathematics is important because it permeates all aspects of daily life, and learning mathematics develops 21st century skills related to critical thinking and problem solving (Goos & Halai 2022). The success of a mathematics education is measured through the abilities of learners to transfer their knowledge and problem-solving skills to new situations. Mathematics Education for Sustainable Development is aimed at inculcating the value of character, skills, attitudes, and knowledge through the application of mathematics learning in the field of environment, social, culture, and economics so that learning mathematics becomes more useful in sustaining their lives adequately and supporting the achievement of Sustainable Development Goal's (SDGs), because there are problems in everyday life that affect the sustainability of human life. It aims to make learning mathematics more meaningful, useful, and support the development of 21st century competences (Widiati & Juandi, 2019).

These competences are based on the Danish KOM Competencies:

A Foundation for Achieving Sustainable Development Goals The Danish KOM competencies, comprising reasoning, problem-solving, communication, modelling, and representation, play a vital role in achieving the United Nations' Sustainable Development Goals (SDGs). These competencies, deeply rooted in mathematics education, empower students with essential skills to address complex global challenges.

Reasoning and critical thinking competencies enable students to make informed decisions, aligning with the SDGs' emphasis on informed decision-making. Problem-solving capacities, fostered through mathematical problem-solving, equip students to tackle intricate global issues. Effective communication of mathematical ideas and solutions facilitates collaboration and information sharing, crucial for SDG achievement. Mathematical modelling skills allow students to comprehend and address complex systems, mirroring the SDGs' focus on holistic solutions. Representation competencies, utilizing various tools, enable students to visualize and interpret data, essential for SDG monitoring and evaluation.

These KOM competencies have direct connections to specific SDGs:

Quality Education (SDG 4) is supported through critical thinking, problem-solving, and communication skills. Decent Work and Economic Growth (SDG 8) are facilitated by problem-solving and modelling competencies, preparing students for innovative careers. Industry, Innovation, and Infrastructure (SDG 9) benefit from modelling and representation competencies, enabling sustainable infrastructure design. Climate Action (SDG 13) is advanced through problem-solving and critical thinking competencies, addressing climate change impacts. Partnerships for the Goals (SDG 17) are fostered through communication and collaboration competencies, promoting global citizenship. The Danish KOM competencies provide a solid foundation for achieving the SDGs. By integrating these competencies into mathematics education, we can empower students with the skills necessary to address complex global challenges, ensuring a more sustainable future.

Interdisciplinary Approaches to Mathematics Education for Sustainable Development

Mathematics education for sustainable development is a multifaceted and interdisciplinary field that draws on diverse perspectives and expertise. Mathematics serves as a foundational cornerstone for various academic disciplines, including engineering and science (Imotor et al, 2024). Consequently, an intrinsic and synergistic relationship exists between mathematics and these fields, fostering a seamless and effective connection that enhances understanding, application, and innovation (Drobnič Vidic, 2023). The pursuit of sustainable development necessitates an integrative approach, combining multiple disciplines to address the complex environmental, social, and economic challenges we face. Effective mathematics education plays a vital role in this endeavor.(Kazanjian, 2019). Mathematics education provides the foundational understanding of mathematical concepts, pedagogies, and assessment strategies essential for tackling sustainability challenges (Stillman & Balatti, 2015). However, it must be integrated with other disciplines to foster a comprehensive approach. Sustainable development encompasses environmental, social, and economic dimensions, requiring an understanding of ecological principles, climate change, and resource management (UNESCO,2019). Education for Sustainable Development (ESD) promotes critical thinking, problem-solving, and civic engagement, empowering individuals to address these challenges (Wals & Corcran, 2012). The social sciences examine human behavior, economic systems, and policy-making, providing valuable insights into the human impact on sustainability (Kates et al. 2001). Cultural studies recognize diverse worldviews, values, and cultural contexts, ensuring inclusive and culturally sensitive solutions (Geertz 1973). Technology and computing leverage digital tools for data analysis, visualization, and simulation, enhancing our capacity to understand and address sustainability challenges (Tsvetovat et al, 2010; Gao et al,2019 and Lu et al, 2020).

Interdisciplinary approaches bridge these disciplines, fostering innovative solutions:

1. STEM Education integrates mathematics, science, technology, and engineering to address sustainability challenges.

2. Environmental Mathematics applies mathematical concepts to ecological systems, climate change, and resource management.

3. Mathematical Modeling uses mathematical models to analyze and solve real-world sustainability problems.

4. Service-Learning combines mathematical concepts with community-based projects, promoting civic engagement and social responsibility.

By embracing these interdisciplinary approaches, mathematics education can contribute meaningfully to sustainable development. Educators must prioritize integrative teaching methods, fostering critical thinking, problem-solving, and civic engagement.

Cross-Disciplinary Collaborations: The Power of Integrating Mathematics

Mathematics, often regarded as the language of science, has the profound ability to transcend disciplinary boundaries. By integrating mathematics with diverse fields, researchers and scholars can unlock innovative solutions to complex challenges. This explores four pivotal cross-disciplinary collaborations: mathematics-economics, mathematics-environmental science, mathematics-social sciences, and mathematics-computer science. The fusion of mathematics and economics enables the examination of economic systems, resource allocation, and sustainability. This integration facilitates data-driven decision-making and policy development, allowing policymakers to make informed choices. For instance, mathematical modeling helps economists understand the impact of climate change on economic growth (Stern, 2007).

The interplay between mathematics and environmental science investigates ecological principles, climate change, and resource management. By employing mathematical modeling, researchers can analyze complex environmental systems and develop sustainable practices (Meadows, 2008). This collaboration has led to significant advancements in climate modeling and predictive analytics. Mathematics and social sciences combine to explore human behavior, policy-making, and social justice. This synthesis provides quantitative insights into societal issues, enabling policymakers to develop evidence-based solutions. For example, mathematical modeling helps inform policy making in social justice (Sampson, 2012). Lastly, the intersection of mathematics and computer science leverages computational thinking, data analysis, and simulation. This partnership enhances problem-solving capacities, driving technological advancements in fields like artificial intelligence and machine learning (Hastie et al, 2009 and Valiat, 2013). These cross-disciplinary collaborations offer numerous benefits such as fostering holistic understanding of complex issues, driving innovative solutions, developing data-driven decision-making, enhancing problem-solving capacities, and informing policy and practice. Integrating mathematics with diverse fields has the potential to revolutionize our approach to complex challenges. By embracing cross-disciplinary collaborations, researchers and scholars can unlock new insights, drive innovation, and cultivate a better future.

The Role of STEM Education in Achieving Sustainable Development

STEM education (Science, Technology, Engineering, and Mathematics) plays a pivotal role in achieving sustainable development. The increasing calls for integrating STEM subjects in school curricula underscore its importance in education (Holmlund et al., 2018; Li, 2019; Morrison & Bartlett, 2009). STEM education uniquely addresses real-world problems in health, energy, and the environment (Durik et al., 2015; Martín-Páez et al., 2019; Struyf et al., 2019). According to Sanders (2009) and National Research Council (2011) STEM education integrates science, technology,engineering and mathematics disciplines which combines science, technology, engineering, and mathematics content and skills. In addition, Lang (2012) posits that STEM education is instrumental in addressing global challenges, such as energy productivity. An integrated STEM approach promises sustainable development education (Nguyen et al., 2020). STEM education tackles global challenges like climate change, poverty, and inequality by developing innovative solutions. By coupling rigorous academic concepts with real-world lessons, STEM education fosters problem-solving, creativity, and critical thinking (Samsudin et al., 2020).

STEM education delivers numerous benefits to students:

- Enhances creativity and problem-solving skills (Suratno et al., 2020)
- Connects school, community, work, and the global enterprise (Bruce-Davis et al., 2014; Hacioglu & Gulhan, 2021)
- Equips students with interdisciplinary knowledge and skills (Nguyen et al., 2020)

Integrated STEM education addresses real-world issues by combining multiple perspectives, skills, and knowledge (Roehrig et al., 2021; Reynante et al., 2020). Kelley and Knowles (2016) define integration as authentic application of STEM knowledge and practices in real-world situations. To cap it up, STEM education is crucial for achieving sustainable development. Its integrated approach develops innovative solutions to global challenges, fosters problem-solving and creativity, and equips students with essential skills and knowledge.

Conclusion

The literature highlights the importance of mathematics education in achieving sustainable development. It shows that Mathematics plays a vital role in various facets of life, cutting across all fields of study, including arts, social sciences, science, technology, medicine, and more. Its applications provide career opportunities in science, engineering, data analysis, economics, computer programming, and more. It is fundamental to problem-solving, critical thinking, and cognitive development. Mathematics education is essential for economic growth, innovation, entrepreneurship, and sustainable development. Interdisciplinary approaches to mathematics education enhance

understanding and application. STEM education is crucial for addressing global challenges. Mathematics education for sustainable development requires integrating mathematical concepts with real-world applications.

Recommendations

1. Interdisciplinary approaches to mathematics education should be integrated.
3. Foster STEM education and its applications.
4. Cross-disciplinary collaborations should be encouraged.
5. Challenges in mathematics education, such as poor student performance and limited resources should be addressed.

By recognizing the importance of mathematics education and implementing these recommendations, we can empower individuals with essential skills, drive innovation, and contribute to sustainable development.

References

Abari, M. T & Durodola, G. T. (2022). Curbing Corruption in Nigeria using Polya's Model of Solving Problems in Mathematics Class. *International Journal of Research*

Agboola, O.S., 2021. Women and STEM Education in Nigeria: Progress, Shortcomings, Challenges, and Way Forward. In *Overcoming Challenges and Barriers for Women in Business and Education: Socioeconomic Issues and Strategies for the Future* (pp. 211-225). IGI Global. DOI: 10.4018/978-1-7998-3814-2.CH011

Adeyemo, S. A. (2017). Challenges Facing Mathematics Education in Nigeria. *Journal of Education and Human Development*, 6(2), 1-9.

Akpotu, N. E. (2019). Factors Affecting Students' Performance in Mathematics in Nigerian Secondary Schools. *International Journal of Educational Research*, 7(1), 1-12.

Bruce-Davis, M. N., Gubbins, E. J., Gilson, C. M., Villanueva, M., Foreman, J. L., & Rubenstein, L. D. (2014, Aug2014). STEM high school administrators', teachers', and students' perceptions of curricular and instructional strategies and practices. *Journal of Advanced Academics, 25*(3), 272-306. https://doi.org/0.1177/1932202X14527952

Danish Ministry of Education. (2019). Kompetencer i Matematik (KOM).

De Corte, E. & Verschaffel, L. (2001). International Encyclopedia of the Social & Behavioral Sciences https://doi.org/10.1016/B0-08-043076-7/02430.X

Doig, B., Williams, J., Swanson, D., Borromeo-Ferri, R., & Drake, P. (Eds.) (2019). *Interdisciplinary mathematics education: The state of the art and beyond.* Springer. https://link. springer.com/book/10.1007/978-3-030-11066-6

Drobnič Vidic, A.(2023). Comparison of Interdisciplinary Connections between Mathematics and other Subjects through Student-Centered Approaches. *REDIMAT – Journal of Research in Mathematics Education, 12(1),* 29-55. doi: 10.17583/redimat.10178

Durik, A. M., Hulleman, C. S., & Harackiewics, J. M. (2015). One size fits some: instructional enhancements to promote interest. *Interest in Mathematics and Science Learning, 1*(1), 49–62. https:// doi. org/ 10. 3102/ 978-0-935302-42-4_3

Gao, J., et al. (2019). Sustainability informatics. Journal of Cleaner Production, 239, 117637.

Geertz, C. (1973). The Interpretation of Cultures. Basic Books.

Goos, M., Halai, A., Dhersin, J.-S., & Kaper, H. (2022). Teaching Mathematics: Mathematics Education for Sustainable Development. In W. Ndifon (Ed.), Mathematics for Action: Supporting Science-Based Decision-Making (pp. 15–16). UNESCO.

Hacioglu, Y., & Gulhan, F. (2021, 18 July 2020). The Effects of STEM Education on the Students' Critical Thinking Skills and STEM Perceptions. *Journal of Education in Science, Environment and Health*, *7*(2), 139-155. https://doi.org/10.21891/jeseh.771331

Hastie, T., Tibshirani, R., & Friedman, J. (2009). *The Elements of Statistical Learning*. Springer.

Holmlund, K., et al. (2018). STEM education: A review of the literature.

Kazanjian, P. (2019). Integrative Approach to Education for Sustainable Development. *Journal of Education for Sustainable Development*, 13(1), 45-56.

Kates, R. W., et al. (2001). Sustainability Science. Science, 292(5517), 641-642.

Kelley, T. R., & Knowles, J. G. (2016). A conceptual framework for integrated STEM education. *Journal of STEM Education, 3*(11), 1-11. doi:10.1186/s40594-016-0046-z

Lang, D.W. (2012). But Will it Be Enough? STEM Education and the Workforce. Issues in Science and Technology

Li, Q. (2019). STEM education in the 21st century.

Lu, J., et al. (2020). Big data analytics for sustainability. *Journal of Cleaner Production*, 251, 119477.

Maass, K., Geiger, V., Romero Ariza, M., & Goos, M. (2019). The role of mathematics in interdisciplinary STEM education. *ZDM Mathematics Education, 51*(6), 869–884. https://doi.org/10.1007/s11858-019-01100-5

Martin-Paez, T., Aguilera, D., Perales-Palacios, F. J., & Vilchez-Gonzalez, J. M. (2019). What Are we talking about when we talk about STEM education? A review of literature. *Science Education, 103*(4), 799–822. https://doi. org/ 10. 1002/ sce. 21522

Meadows, D. H. (2008). *Thinking in Systems*: A Primer. Chelsea Green Publishing.

Morrison, J., & Bartlett, R. (2009). STEM education: The foundation of the 21st-century economy.

National Research Council (2011). Successful STEM Education.

Nguyen, T. P. L., Nguyen, T. H., & Tran, T. K. (2020). STEM education in secondary schools: Teachers' perspective towards sustainable development. *Sustainability (Switzerland), 12*(21), 1-16, Article 8865. https://doi.org/10.3390/su12218865

OECD. (2019). PISA 2018 Results: What Students Know and Can Do.

Ogunniyi, M. B. (2014). Mathematics Education in Nigeria: Issues and Prospects. *Journal of Mathematics and Statistics*, 10(2), 1-8.

Reynante, B. M., Selbach-Allen, M. E., & Pimentel, D. R. (2020). Exploring the promises andperils of integrated STEM through disciplinary practices and epistemologies. *Science & Education, 29*(4), 785-803. https://doi.org/10.1007/s11191-020-00121-x

Roehrig, G. H., Dare, E. A., Ring-Whalen, E., & Wieselmann, J. R. (2021, Jan 2021). Understanding coherence and integration in integrated STEM curriculum. *International Journal of STEM Education, 8*(1). https://doi.org/10.1186/s40594-020-00259-8

Sampson, R. J. (2012). *Great American City: Chicago and the Enduring Neighborhood Effect.* University of Chicago Press.

Samsudin, M. A., Jamali, S. M., Zain, A. N. M., & Ale Ebrahim, N. (2020, March). The Effect of STEM Project Based Learning on Self-Efficacy among High-School Physics Students. *Journal of Turkish Science Education, 17*(1), 94-108. https://doi.org/10.36681/tused.2020.15

Sanders, M. (2009). STEM education. STEMmania. *The Technology Teacher*, *68*(4), 20-26.

Stern, N. (2007). The Economics of Climate Change: The Stern Review. Cambridge University Press.

Struyf, A., De Loof, H., Boeve-de Pauw, J., & Van Petegem, P. (2019). Students' engagement in different STEM learning environments: integrated STEM education as promising practice? *International Journal of Science Education, 41*(10), 1387–1407. https:// doi. org/ 10. 1080/ 09500 693. 2019.16079 83

Stillman, G., & Balatti, J. (2015). Mathematical Modelling in Education Research and Practice. Springer.

Suratno, S., Wahono, B., Chang, C. Y., Retnowati, A., & Yushardi, Y. (2020). Exploring a Direct Relationship between Students' Problem-Solving Abilities and Academic Achievement: A STEM Education at a Coffee Plantation Area. *Journal of Turkish Science Education, 17*(2), 211-224. https://doi.org/10.36681/tused.2020.22

Tsvetovat, M., et al. (2010). Computational sustainability. Communications of the ACM, 53(10), 34-36.

Tytler, R., Prain, V., Kirk, M., Mulligan, J. T., Neilsen, C., Speldewinde, C., White, P., & Xu, L. (2022). Characterizing a representation construction pedagogy for integrating science and mathematics in the primary school. *International Journal of Science and Mathematics Education*. https://doi.org/10.1007/s10763-022-10284-4

UNESCO. (2019). Education for Sustainable Development Goals: Learning Objectives. Paris: UNESCO United Nations. (2020). Sustainable Development Goals.

Valiant, L. G. (2013). Big Data: A New Paradigm. *ACM Transactions on Database Systems*, 38(1), 1-11

Wals, A. E. J., & Corcoran, P. B. (2012). Learning for Sustainability in Times of Accelerating Change. *Journal of Sustainability Education*, 3

Widiati, I., & Juandi, D. (2019) *J. Phys.: Conf. Ser*. **1157** 022128