

MICROBIAL FUEL CELL: A NEW APPROACH OF GREEN TECHNOLOGY IN BIOLOGY CURRICULUM

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Published: 26 July 2023

To cite this article (APA): Man, S. R., Ishak, N. A., & Makhtar, M. M. Z. (2023). Microbial Fuel Cell: A New Approach of Green Technology in Biology Curriculum. *Jurnal Pendidikan Bitara UPSI*, 16, 190–198. <https://doi.org/10.37134/bitara.vol16.sp2.18.2023>

To link to this article: <https://doi.org/10.37134/bitara.vol16.sp2.18.2023>

ABSTRACT

Green technology can be described as the use of environmental science to conserve resources and the natural environment as well as control negative impacts on human daily activities. In order to inculcate students' interest in environmental issues, many initiatives have been taken, including the implementation of a green technology syllabus into the current Biology curriculum. Students should also have a better understanding of green technology as early as possible because this approach is very important in curbing negative human activities on earth. The purpose of this paper is to provide information related to environmental education, education for sustainable development, and a new approach of green technology, which is Microbial Fuel Cell (MFC). In line with the transformation of the Biology curriculum, MFC has the potential to be integrated into the Biology curriculum, since it is very useful to educate students and increase their interest in environmental education. This is due to environmental problems that arise globally, including climate change and global warming; but the knowledge among the community is still at a low level. Additionally, the current Biology curriculum focuses on environmental sustainability, which is connected to the implementation of green technology. Hence, MFC is one of the green technology approaches that can be used to educate students and increase their knowledge about environmental education.

Keywords: Green technology, Microbial Fuel Cell (MFC), environmental education (EE), education for sustainable development (ESD), Biology curriculum

INTRODUCTION

Recently, climate change has become one of the most pressing environmental issues worldwide. According to Rebecca and Luann (2023), Earth's temperature has risen since 1880; by an average of 0.14° Fahrenheit, which is 0.08° Celsius per decade. Sea levels will undoubtedly rise as a result of global warming, and even a slight increase might significantly harm small islands and low-lying beaches. Several efforts have been made to address these issues, including The Montreal Protocol (1987), the IPCC (International Panel on Climate Control, 1988), the Earth Summit (1992), and the Millennium Ecosystem Assessment (2005) (Petsonk, 1990). Malaysia also participated in the COP26 conference, or United Nations Framework Convention on Climate Change, which was held in Glasgow, Scotland, to address global environmental issues. Apart from that, the use of technology and science to reduce human impacts on the natural environment has also been emphasized, which is known as green technology.

Malaysia has the potential to develop green technology that not only benefits the national economy but also supports environmental sustainability (Nor Farahin Jasmi & Arasinah Kamis, 2019) because, through green technology, the environment can be preserved due to the reduction of human activities (Mohd Wira & Hooman Abadi, 2017). In line with the Sustainable Development Goals (SDG), education about climate change and environmental degradation is a vital instrument for reducing

the severity of the current climate crisis (UNICEF, 2019). By using the approaches of environmental education (EE) and Education for Sustainable Development (ESD), green technology is an effective way to minimize the effect of climate change and build the capacity to adapt to its impending negative effects.

The focus of green technology is on skills to deal with environmental problems (Margin et al., 2013) and the social responsibility of society (Yean & Suzieleez Syrene, 2021). Among the approaches that can be taken is through Microbial Fuel Cells (MFC), which can generate electricity from chemical energy produced from the decomposition of organic substrates, including wastewater, through electrogenic bacteria (Khairul Baqir et al., 2018) and inorganic substrates (Mohd Imran Ahamed & Naushad Anwar, 2022). MFC is also seen as having the potential to reduce energy resource problems, wide demand gaps, and global climate change (Shah et al., 2019). The students not only get a better-quality education, but are also able to support the government's efforts to reduce environmental problems while preserving all life in an effort to reduce the impact of human activities on the world's climate.

In line with the transformation of curriculum, the education system in Malaysia has also been transformed tremendously from Integrated Based Curriculum for Secondary Schools (KBSM) to Standard Based Curriculum for Secondary Schools (KSSM) in terms of content, pedagogy, and assessments. Integration of cross-curricular elements such as green technology into Biology curriculum (Ministry of Education, 2020; Mohd Wira Mohd Shafiei & Hooman Abadi, 2017; Siti Rohana Man et al., 2023) seems to help the government address environmental issues, such as climate change and environmental degradation, from an early age. Since environmental education helps students gain more knowledge about their surroundings and develop skills needed to deal with challenging environmental problems, a green technology approach such as MFC is very effective in educating them on how to practice reduce, reuse, and recycle (3R) (Rocky Maharjan et al., 2023).

METHODOLOGY

This concept paper was done based on the collection of information and materials related to environmental education and green technology in Malaysia's current curriculum. Literature review and document analysis has been studied to provide information related to environmental education, education for sustainable development, and a new approach of green technology, which is Microbial Fuel Cell (MFC).

Development of Environmental Education (EE) And Education for Sustainable Development (ESD) in Curriculum

According to Zuhaira Nasrin and Zul'azmi Yaakob (2020), education is the best way to disseminate EE and create a magnificent society from an economic, political, and social standpoint. Various international and national discussions over the past few decades, including the Stockholm Conference (1972), the Belgrade Charter (1975), the Tbilisi Conference, Georgia (1977), Malta (1991), Agenda 21 (1991), and the Earth Summit (1992), have highlighted its role in advancing EE (Nurul Hidayah et al., 2013). Apart from that, the Kyoto Protocol and the Paris Agreement conference, which highlighted climate change, were held every year from 1995 in Berlin until 2019 in Madrid (KPM, 2010; Mohd Azmi Abdul Hamid, 2020). Although various conferences related to EE are held globally, the Stockholm Conference (1972) was the starting point of a major change in EE. The world community acknowledged EE and its development as a tool for the understanding, preservation, and improvement of the environment (United Nations, 1972; UNESCO-UNEP, 1976).

In Malaysia, a Cabinet Committee was established in 1974 to review the National Education Policy. This aims to improve the implementation of the curriculum in order to produce a united and disciplined society and meet the needs of the people who are trained for national development (Saharia Ismail, 2015). As a result, the Committee Report published in 1979 decided on the implementation of EE across the curriculum for the New Primary School Curriculum (KBSR) and the Integrated Secondary School Curriculum (KBSM) (Haliza Abdul Rahman, 2017). The implementation of EE

across the curriculum was first introduced and implemented in 1982 in 305 primary schools and subsequently implemented in all primary schools in 1983 (Zuhaira Nasrin & Zul'azmi Yaakob, 2020). Then, in 1986, this education was applied across the curriculum for Man and Environment subjects (Azlinawati Abdullah et al., 2018; Hanifah Mahat et al., 2018; Nurul Hidayah et al., 2013), which involved a combination of Geography, Science, History, Moral Education, and also Physical and Health Education subjects (Zuhaira Nasrin & Zul'azmi Yaakob, 2020). In 1989, the topic of EE was incorporated into the subjects of Geography and Science, and the Integrated Curriculum for Secondary Schools (KBSM) was used to coordinate its inclusion in the subjects of Biology, Physics, and Chemistry. Since 1998, EE across the curriculum has been introduced more widely into the syllabus of primary and secondary school subjects (Ministry of Education, 2001; Noraziah Mhd Yusop & Latipah Sidek, 2010). The goals of EE as set in the Man and Environment subject are not fully achieved because less emphasis is placed on the application of moral values, decision-making skills, and solving problems related to the environment (Haliza Abdul Rahman, 2017; Hanifah Mahat et al., 2018).

Global climate change and dramatic challenges, together with the development of curriculum, lead to ESD. ESD is characterized as an educational innovation that originated in EE. It is hoped that the younger generation will understand the need to protect the environment. resources for both the present and the future. The primary thematic area of ESD is climate change education, which equips people with the knowledge, abilities, values, and attitudes necessary to act as change agents by assisting them in understanding and addressing the effects of the climate crisis (UNESCO, 2023). ESD can also be considered a creative education that can address current and future global challenges by creating a more sustainable and resilient society. ESD is one of the quality education that is responsible for environmental integrity, economic viability, and shaping a society for present and future generations. ESD is also a holistic education and transformation approach to dealing with learning content, pedagogy, and learning in the environment (UNESCO, 2017). The Education 2030 Framework for Action also states that educational institutions and programs need to have sufficient and equitable funding, as well as access to technology, books, and other learning resources that are non-discriminatory, conducive to learning, learner-friendly, context-specific, cost-effective, and available to all learners, including children, youth, and adults. Thus, more teaching and learning resources and activities should be upgraded in order to educate students with ESD.

In line with that, ESD is one of the most effective ways to expose students to environmental issues at the school level, so that the current generation will appreciate environmental protection for future generations. In that sense, ESD can be integrated into Biology curriculum, along with the transformation of KBSM into KSSM. Several approaches can be implemented, including the integration of green technology into the current curriculum. By implementing EE and ESD strategies and adopting educational approaches, green technology is expected to assist social and environmental activities (Hanifat Mahat et al., 2015; Egana del Sol, 2019). By using the Biology Curriculum Specification (HSP) KBSM as a master guideline, cross-curricular elements (EMK) have been drafted in the latest Biology KSSM, including elements of environmental sustainability. In addition to that, one of the themes included in KSSM Biology is Ecosystem and Environmental Sustainability (Ministry of Education, 2018). The EE that is incorporated into KSSM Biology is very important in order to educate students about environmental issues. This is supported by Suhaili and Hafsa (2021), where education is the best channel for forming and shaping a generation that has knowledge, awareness, and sustainability practices. Previous studies have shown that EE is more related to Biology subjects than to Physics and Chemistry subjects (Sharifah Intan Sharina et al., 2011) (Table 1). In addition to its obvious relevance to environmental sustainability, biology can positively contribute to sustainable development in the areas of social, economic, and cultural issues.

Table 1 Checklist of environmental knowledge application across the curriculum of science subjects

Environmental Knowledge	Biology Form 4	Biology Form 5	Physics Form 4	Physics Form 5	Chemistry Form 4	Chemistry Form 5
What Is Ecology? What Do Ecologists Do?	X				X	
Individuals, Populations, and Levels of Organization in Ecology	X					
The Ecosystem Concept Develop	X					
Energy and Ecosystems			X		X	X
Ecological Succession	X					
Populations and Their Dynamics	X					
Humans as an Ecological Factor	X					
Humans: Their History of Resource Consumption						X
Soils and Allied Problems	X					
Water and Allied Problems	X					
Food Production and Hunger	X				X	X
Forest Resources	X					
Plant and Animal Resources	X					
Air Pollution	X				X	X
Water Pollution	X				X	X
Noise Pollution	X					X
Solid Waste Disposal						
Hazardous Waste					X	
Human Population Growth and Control	X	X				X

Source: Sharifah Intan Sharina (2011)

ESD is the approach that not only provides theoretical information to people about sustainability but also gives them practical tools, to move society towards sustainability (Syarina Ramli et al., 2019). With the implementation of the green technology syllabus into Biology curriculum, students will be engaged with environmental issues, thus encouraging them to practice 3R in their daily lives. This is supported by Nor Farahin Jasmi and Arasinah Kamis (2019), where green technology is the main force of ESD, which is crucial for students and the community.

Implementation of Green Technology in Education

The green technology revolution in Malaysia has improved since the Ministry of Energy, Green Technology, and Water (KeTTHA) was established in 2009. In order to achieve an economic paradigm shift, the government plays a significant role in supporting green technology in all kinds of development. As a result, the government has taken the initiative to analyze the curriculum and curriculum relating to green technology at the preschool, primary, and secondary school levels (Nor Farahin Jasmi & Arasinah Kamis, 2019; Siti Nor Syazwani et al., 2012). The National Green Technology Policy (NGTP) was launched by KeTTHA to support green technology as a catalyst for economic progress towards sustainable development (NGTP, 2009). Since then, more initiatives on green technology have been launched, for example, the Malaysian Green Technology and Climate Change Corporation (MGTC), which is directly involved in driving climate change mitigation actions such as advocacy for energy efficiency and renewable energy, low-carbon urban programs, and low-carbon mobility (MGTC, 2023).

A product, piece of machinery, or system is considered "green technology" if it minimizes the degradation of the environment, emits little to no greenhouse gases (GHGs), is safe to use, provides a better environment for all living things, conserves natural resources, and supports renewable resources (NGTP, 2009). NGTP also states that local research institutions and institutions of higher learning should develop research, development, and innovation activities on green technology towards commercialization through appropriate mechanisms. However, there is still a lack of emphasis on EE involving green technology among school students. In relation to that, together with KeTTHA and the Ministry of Education, curriculum transformation should be done because green technology elements are highly emphasized in education. This is supported by Anusuya Kaliappan and Hashima Hamid

(2021), where the idea of green technology should be integrated into the curriculum, learning content, and teaching and learning process.

A study conducted by Anissa Lestari Kadiyono et al. (2019) proposed a learning model to introduce green technology and improve green practices among students. This qualitative study was conducted based on observation and group discussion. The results of this qualitative study showed that there is a need for learning material related to green technology in education. Next, studies involving green technology are more emphasized in Technical and Vocational Education and Training, or TVET (Anusuya Kaliappan & Hashima Hamid, 2021; Nor Farahin Jasmi & Arasinah Kamis, 2019). The findings of the study showed that green technology is one approach that can be emphasized in education to improve and meet the demands of the local industry. Green technology is also one of the EEs that can change the perception and actions of the community, especially to achieve environmental sustainability. Based on a study conducted by Farahwahida Mohd Yusof et al. (2013), the application of green technology in everyday life can be practiced in the simplest way. For example, bring a drinking water bottle from home instead of buying a new one. In addition, we are also advised to practice a green lifestyle effectively, for example, by reducing domestic waste, practicing recycling, and using kitchen waste as compost to fertilize the soil. Other than composting, all solid wastes can be used as substrates in a new approach of green technology, which is Microbial Fuel Cell (MFC).

Microbial Fuel Cell (MFC)

Microbial Fuel Cell (MFC) is a branch of green technology that can directly transform chemical energy in organic matter into electrical energy by using electricity-producing microorganisms as anode catalysts (Chaturvedi & Verma, 2016). MFC can be classified as the new approach for preserving natural resources because MFC can operate in diversified areas such as renewable energy and solid waste management (Mohd Wira Mohd Shafiee & Hooman Abadi, 2017). MFC is one of the renewable energy alternatives that has drawn interest due to its capability to generate electricity and treat wastewater. (Amirul Amin Mohd Nazri, 2019; Khairul Baqir Alkhair et al., 2018). Electrogenic bacteria are used in the field of MFC to create chemical energy from the breakdown of organic and inorganic substrates (Khairul Baqir Alkhair et al., 2018; Inamuddin & Abdullah, 2017). According to earlier research (Roy et al. 2017; Shah et al. et al. 2019), MFCs are used in wastewater treatment, microbial solar cells, bioelectricity generation, recovery of industrial chemicals, pollution removal, microbial desalination cells, sensors, hydrogen production, bioremediation, and energy recovery. Diagram 1 shows the MFC set up in the laboratory, which consists of graphite electrodes, anode and cathode, plastic containers, alligator clips, a digital multimeter, and resistors (Muhammad Izzat Nur Ma'arof et al., 2018).

Diagram 1 Set up of Microbial Fuel Cell (MFC)



The main concept of bacterial respiration has been covered at the lower secondary level, and the most recent green technology, such as MFC, is particularly suitable to be integrated into Biology curriculum. Since MFC is a green technology activity that uses clean, energy-efficient, and non-toxic power generation (Chaturvedi & Verma, 2016; Logan, 2004), activities related to MFC are very suitable to be applied in EE themes in Biology KSSM in order to enhance the students' knowledge on green technology. MFC also supports green technology because MFC is a new approach of green technology that can remediate trash and recover energy from biomass using a variety of solid food wastes to produce bioelectricity (Dilip Kumar et al., 2021). Due to MFC's ability to dispose of trash while simultaneously generating energy, its use in composting appears promising given the rise in solid waste. This is suitable to be infused with the current Biology curriculum, since the activity regarding composting is not emphasized in the green technology subtopic. There is only one activity regarding green technology, which is the eco-enzyme production covered in the Form 5 Biology syllabus (MOE, 2020).

Additionally, the Ministry of Education's analysis of the use of green technology in preschools, primary schools, and secondary schools found that the integration of green technology topics in the curriculum is thorough and should be updated in accordance with students' comprehension levels (Syarina Ramli et al., 2019). All practices regarding waste management are very important in order to prepare the young generation, especially students, with appropriate skills regarding solid waste management and other green technology practices in their daily lives. Thus, students will become more knowledgeable and aware of environmental issues, because they are engaged in learning processes outside of the classroom. This is supported by Gamage et al. (2022), where providing students with the necessary knowledge, awareness, and abilities while also nurturing the next generation of leaders and innovators may be able to bring about the necessary change and have a significant impact on the path to a sustainable future.

CONCLUSIONS AND FUTURE RECOMMENDATIONS

Microbial Fuel Cell (MFC) is a new approach of green technology that can be applied in environmental education (EE) and education for sustainable development (ESD) as it involves the concept of preserving natural resources. Furthermore, the current Biology KSSM curriculum emphasizes the green technology subtopic, which is very important to educate and impart students' interest in environmental issues. Thus, more teaching and learning materials, including recent approaches in green technology, need to be developed in order to engage students with environmental problems, especially hands-on MFC activities. This, in turn, will empower students with the skills to handle environmental problems and issues in a proper manner. Apart from that, the favorable effects of EE and ESD on human welfare and world development are well acknowledged. If everyone wishes to put a stop to unhealthy thought and practice patterns, Malaysia's educational system needs to be completely reformed to guide each person into a secure and fruitful future. Activities regarding environmental curriculum that align with instruction about ESD, especially the inclusion of green technology components to address environmental issues, are very important to educate students regarding the surrounding environment.

ACKNOWLEDGEMENT

This paper is funded by an APEX ERA Research Grant from Universiti Sains Malaysia (1001.PGURU.881007). A special thanks to USM for the funding and encouragement to run this research. The authors would like to thank the Ministry of Education (MOE), under the sponsorship of the Hadiah Latihan Persekutuan (HLP) and Universiti Sains Malaysia (USM), for the support, advice, and guidance for this study.

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