Volume: 10 Issues: 73 [June, 2025] pp. 63 - 78
Journal of Islamic, Social, Economics and Development (JISED)
eISSN: 0128-1755
Journal website: www.academicinspired.com/jised
DOI: 10.55573/JISED.107306

STEM TEACHERS' PERCEPTIONS AND ATTITUDES TOWARDS SUSTAINABLE DEVELOPMENT: A NEEDS ANALYSIS

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Article history
Received date : 26-5-2025
Revised date : 27-5-2025
Accepted date : 20-6-2025
Published date : 24-6-2025

To cite this document:
Rosman, N., Hashim, H., & Hamid, J. (2025). STEM teachers' perceptions and attitudes towards sustainable development: A needs analysis. *Journal of Islamic, Social, Economics and Development (JISED),* 10 (73), 63- 78.

Abstract: *Ongoing transformations brought about by globalization, both broadly and within specific societal contexts have opened new avenues for re-evaluating and formulating more strategic and effective approaches toward sustainable development (SD) in human lifestyles. This shift is exemplified by the initiative of the United Nations Educational, Scientific and Cultural Organization (UNESCO), which outlined an educational roadmap in 2020 to support sustainable development goals. In line with this, the present study aims to explore the levels of perception and attitudes among Science, Technology, Engineering, and Mathematics (STEM) subject teachers regarding sustainable development. Employing a descriptive survey design, this study involved a total of 161 secondary school teachers from various schools across the northern, central, eastern, and southern zones of the country. A structured questionnaire was used as the primary research instrument, and the data collected were analyzed using the Statistical Package for the Social Sciences (SPSS) version 26.0 to compute percentages, mean scores, and standard deviations. The findings indicate that STEM teachers demonstrated a high level of perception toward sustainable development (M = 4.30, SD = 0.640), as well as a similarly high level of positive attitudes (M = 4.24, SD = 0.716). Overall, this study provides valuable insights into the readiness, awareness, and positive disposition of STEM educators in addressing global changes that are closely linked to sustainable development, particularly within the national education context.*

Keywords: *Sustainable development, STEM education, teacher perceptions, educational sustainability.*

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Introduction

The concept of sustainability and sustainable development encompasses a broad and interdisciplinary scope within scientific research, particularly in relation to environmental concerns, natural resource management, and the domains of industrial and agricultural production (Ruggerio, 2021). According to Dewan Bahasa dan Pustaka (DBP), the term sustainable refers to the ability to consistently maintain desirable outcomes or achievements. In a broader sense, it denotes the capacity to uphold a system or process at a stable and continuous level over time.

The term sustainable development gained global prominence with its formal introduction in the Report of the World Commission on Environment and Development (1987), commonly known as the Brundtland Report. This seminal document emphasized that present-day actions must not compromise the ability of future generations to meet their own needs. Sustainable development is thus defined as "development that meets the needs of the present without compromising the ability of future generations to meet their own needs" (Gibbs, 2021).

Sustainable development has since evolved into a global agenda committed to ensuring the well-being of both current and future generations. The Sustainable Development Goals (SDGs), introduced by the United Nations (UN) in 2015, call for systematic transformation across multiple sectors, including education (UNESCO, 2020). In response, the approach of Education for Sustainable Development (ESD) was introduced to equip learners with the knowledge, values, and competencies necessary to make informed decisions and act responsibly in environmental, economic, and social contexts.

Science, Technology, Engineering, and Mathematics (STEM) education is viewed as a strategic platform for advancing sustainability due to its relevance in fostering innovation and developing solutions to global challenges (Bybee, 2023). Integrating sustainability values into STEM curricula helps to enhance students' awareness of critical issues such as climate change, responsible resource management, and ethical decision-making (Ng & Lee, 2021). In this regard, STEM teachers play a pivotal role as change agents in embedding sustainability meaningfully into classroom instruction.

However, the effective implementation of ESD in STEM education is contingent upon teachers' perceptions, attitudes, and readiness. Teachers who understand and value the importance of sustainable development are more likely to integrate these concepts into their pedagogical practices (Olsson et al., 2016). Conversely, teachers with limited conceptual understanding or negative attitudes may apply ESD superficially, limiting its impact.

Although sustainable development has been explicitly emphasized in national education policies such as the Malaysia Education Blueprint 2013–2025, evidence suggests that the actual integration of ESD within STEM instruction in schools remains inadequate (Ministry of Education Malaysia, 2023). Numerous studies highlight that many teachers face conceptual confusion and lack access to suitable pedagogical models for incorporating sustainability (Noraini et al., 2022; Abdul Razak et al., 2020). This often results in fragmented or inconsistent delivery of sustainability content in the classroom.

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Furthermore, teachers' attitudes toward sustainable development significantly affect their motivation to teach sustainability-related themes. Those who do not perceive sustainability as directly relevant to their subject areas may be less inclined to adopt ESD approaches (Sund & Lysgaard, 2023). Compounding this issue are systemic challenges such as excessive workloads, limited training opportunities, and a lack of adequate teaching materials (Saavedra & Opfer, 2022).

While previous literature indicates that teachers generally express positive views about STEM education and the ideals of sustainable development, there remains a critical gap between awareness and actual implementation. Specifically, there is limited empirical evidence on the extent to which STEM teachers in Malaysia understand, value, and apply ESD principles in their teaching practices. Additionally, a clear understanding of the specific training and systemic support they require remains underexplored. Without addressing this gap, efforts to mainstream sustainability education through STEM risk being ineffective or unsustainable.

Therefore, this study aims to examine the levels of perception and attitudes among STEM teachers toward sustainable development and to identify the training and support structures necessary to strengthen ESD implementation at the classroom level. Conducting such a needs analysis is vital for laying the groundwork for more targeted professional development and policy interventions that support the integration of sustainability in STEM education across Malaysian schools.

Literature Review

Sustainable Development (SD)

According to the Second Edition of the Student's Dictionary, development refers to the act of developing something namely the process of advancing and expanding. The term sustainable denotes the ability to continue growing while maintaining a satisfactory level of performance. In alignment with this definition, the landmark report Our Common Future published by the World Commission on Environment and Development (WCED) in 1987 defines sustainable development as development that meets the needs of the present generation without compromising the ability of future generations to meet their own needs.

Several researchers have indicated that the emergence of the sustainable development concept can be traced back to the early 1970s (Mebratu, 1998; Mitlin, 1992), primarily due to growing concerns over the negative impacts of development on the environment. Sustainable development is fundamentally based on an integrative perspective that interweaves three core dimensions—economic, social, and environmental. The sustainability of these three pillars is essential, and they must be properly implemented and integrated in order to achieve the fundamental goals of sustainability (DESA-UN, 2018). Mensah (2019) also asserted that the success of sustainable development heavily relies on the balanced achievement of these three dimensions, as they are inherently interconnected.

The Sustainable Development Goals (SDGs) established by the United Nations (UN) and adopted globally in 2015 encompass targets such as poverty eradication, climate change mitigation, and universal access to quality education. The SDGs offer a universally accepted

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framework of sustainability objectives and targets aimed at promoting global development in a more inclusive and responsible manner.

The implementation of the SDGs, formally endorsed by the international community during the Rio+20 United Nations Conference on Sustainable Development held in Brazil in 2012, is widely regarded as a culmination of extended debates and a significant milestone in global efforts to address social, economic, and environmental development challenges (Chin et al., 2019).
A total of 17 Sustainable Development Goals, as outlined in Table 1, serve as a blueprint for action to enhance the quality of life and foster a more equitable and sustainable future for all (United Nations Department of Economic and Social Affairs, 2019).

To achieve these goals, various governmental and private sector agencies across different domains have been actively focusing on and implementing appropriate strategies. One of the key sectors contributing to sustainable development is the industrial sector. The ongoing shift towards Industry 5.0 presents new opportunities for this sector to play a pivotal role in promoting sustainability and advancing environmental stewardship.

Table 1: 17 Sustainable Development Goals (SDGs)

Goal	Sustainable Development Goal (SDG)	Description
1	No Poverty	End poverty in all its forms everywhere.
2	Zero Hunger	End hunger, achieve food security, improve nutrition, and promote sustainable agriculture.
3	Good Health and Well-being	Ensure healthy lives and promote well-being for all at all ages.
4	Quality Education	Ensure inclusive and equitable quality education and promote lifelong learning opportunities.
5	Gender Equality	Achieve gender equality and empower all women and girls.
6	Clean Water and Sanitation	Ensure availability and sustainable management of water and sanitation for all.
7	Affordable and Clean Energy	Ensure access to affordable, reliable, sustainable, and modern energy for all.
8	Decent Work and Economic Growth	Promote sustained, inclusive, and sustainable economic growth, full and productive employment, and decent work for all.
9	Industry, Innovation and Infrastructure	Build resilient infrastructure, promote inclusive and sustainable industrialization, and foster innovation.
10	Reduced Inequalities	Reduce inequality within and among countries.
11	Sustainable Cities and Communities	Make cities and human settlements inclusive, safe, resilient, and sustainable.
12	Responsible Consumption and Production	Ensure sustainable consumption and production patterns.
13	Climate Action	Take urgent action to combat climate change and its impacts.

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14	Life Below Water	Conserve and sustainably use the oceans, seas, and marine resources.
15	Life on Land	Protect, restore, and promote sustainable use of terrestrial ecosystems, manage forests sustainably, combat desertification, and halt biodiversity loss.
16	Peace, Justice and Strong Institutions	Promote peaceful and inclusive societies, provide access to justice for all, and build effective, accountable institutions.
17	Partnerships for the Goals	Strengthen the means of implementation and revitalize the global partnership for sustainable development.

Source: Chin et al., (2019)

Education for Sustainable Development (ESD)

Education for Sustainable Development (ESD) is a term that has only emerged in recent decades. ESD originated from earlier Western initiatives such as environmental education, which gained momentum in the United States in the 1970s (Carter & Simmons, 2010). In 2002, world leaders convened at the World Summit on Sustainable Development to propose and adopt a resolution for a ten-year effort towards ESD, beginning in January 2005. Throughout the decade of ESD implementation, progress toward achieving its targets was minimal. As the ten-year ESD period approached its end in 2015, global leaders at the United Nations Conference on Sustainable Development in 2012 acknowledged the limited outcomes and doubled their commitment to ESD by agreeing to continue efforts beyond the original ten-year commitment. Ultimately, ESD was placed at the core of the United Nations' 2030 Agenda for Sustainable Development (Leicht, 2018).

Since ESD is one of the targets of the United Nations' Sustainable Development Goals (SDGs), schools implementing ESD are encouraged to consider environmental, economic, and social sustainability through various pedagogical approaches. According to the Global Action Programme (GAP), implemented by UNESCO to support the achievement of ESD, schools should empower learners with skills, knowledge, values, and attitudes to contribute effectively to sustainable development (UNESCO, 2014). Rather than delivering these skills separately, ESD practitioners and organizers advocate a holistic approach that integrates and weaves all skills as seamlessly as possible into the curriculum (Bagoly-Simo, 2013; Burns, 2018; Jackson, 2009). Therefore, instead of viewing ESD as an additional element to be inserted into existing best practices, ESD itself should serve as the foundation of best practice thinking, informing curriculum decisions and thereby building connections among all learning activities within a school.

"ESD for 2030" was launched at an international conference organized by UNESCO and supported by the German government as the host. The conference aimed to provide momentum to further strengthen ESD in educational policies and practices and to guide the strategic design of new programs. It was held from May 17 to 19, 2021, in Berlin. Additionally, a National Launch Conference commenced the program in Germany on May 19, 2021.

The goals of ESD for 2030 aim to build a more just and sustainable world through strengthening ESD and contributing to the achievement of the 17 SDGs. Its objectives

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include the full integration of ESD and the 17 SDGs into policy, learning environments, capacity building of educators, empowerment and mobilization of youth, and local-level actions. The approach is holistic and transformative, encompassing learning content and outcomes, pedagogy, and the learning environment itself. ESD is recognized as an enabler of all SDGs and achieves its aims by transforming societies through the core pillars of ESD, which are:

1) Societal transformation: Enabling SDG achievement towards building a more sustainable world through learning;
2) Learning outcomes: Empowering individuals to take responsibility for present and future generations and to actively contribute to societal transformation;
3) Learning content: Integrating sustainability issues, especially those outlined in the 17 SDGs such as climate change, into all forms of learning;
4) Pedagogy and learning environments: Employing interactive, project-based, learner-centered pedagogy. Transforming all aspects of the learning environment through a whole-institution approach to ESD to enable learners to experience and embody what they learn.

The new framework, called ESD for 2030, is a global framework for ESD implementation from 2020 to 2030, aiming to advance actions from the United Nations Decade of Education for Sustainable Development (UN DESD) (2005-2014) and the Global Action Programme (GAP) on ESD (2015-2019). The ESD for 2030 framework is built on lessons learned from previous ESD reports (2015-2019), which highlighted the growing importance of ESD in promoting learning content that contributes to human autonomy and prosperity.

Accordingly, the new ESD for 2030 framework places transformative action as a critical aspect of ESD, where ESD is expected to empower learners to transform themselves and society to address current global challenges and build a better world. Through ESD, specific cognitive, socio-emotional, and behavioral learning outcomes enable individuals to tackle particular challenges related to each SDG, thereby facilitating their achievement. This will equip them with the knowledge and competencies necessary to bring about the required transformations.

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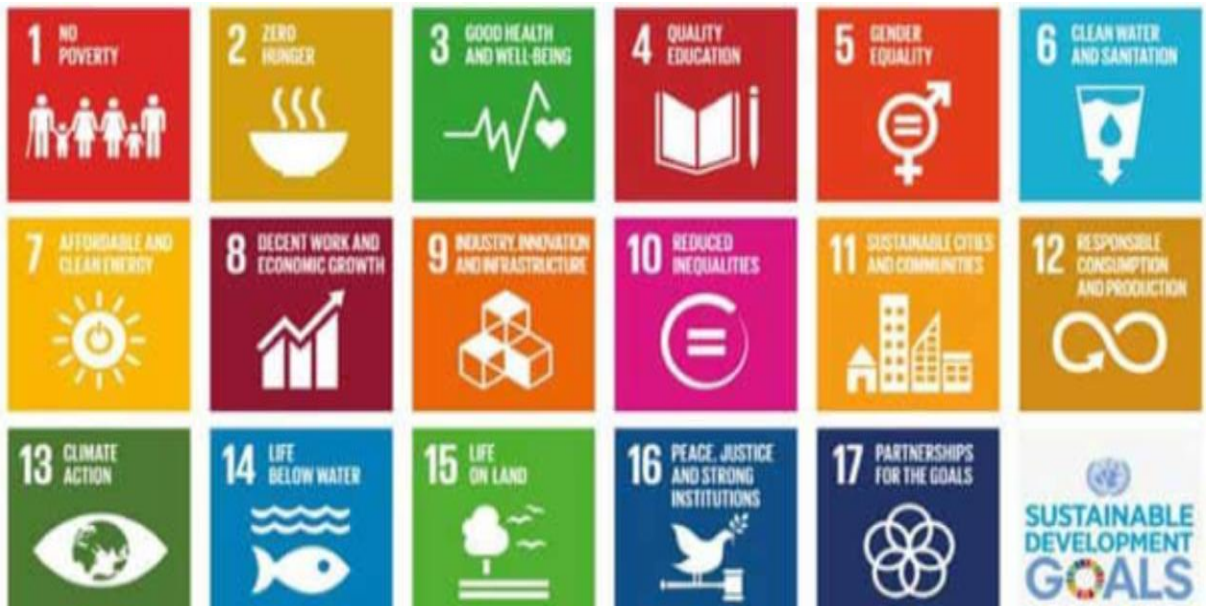

Figure 1: ESD Framework for 2030. Source: UNESCO (2019)

STEM education is considered a key vehicle for achieving sustainability due to its potential for innovation and problem-solving (Bybee, 2023). Integrating ESD into STEM subjects can equip students with scientific literacy and a sustainability mindset to address global issues like energy consumption, environmental degradation, and climate change (Ng & Lee, 2021).

However, the actual implementation of ESD in STEM classrooms remains uneven. While some studies show that STEM subjects naturally lend themselves to ESD integration (Chin et al., 2019), others argue that science and math teachers struggle to connect disciplinary content with broader sustainability themes (Noraini et al., 2022). This inconsistency may stem from a lack of pedagogical training or resources that frame STEM learning within sustainability contexts.

Factors Influencing the Implementation of Education for Sustainable Development

Education for Sustainable Development (ESD) is also influenced by other factors. Among these are the changing global conditions post-pandemic and the worldwide climate change, which affect the sustainable development of the regional education sector. According to a UNESCO (2020) study, these conditions are attributed to the following:

a) Nearly half, or 47 percent, of the national curriculum frameworks from 100 reviewed countries, including Malaysia, do not reference climate change. The remainder mention climate change in their documents but only minimally and generally lack detail.
b) In a review of the profiles of 20 countries, guidelines or frameworks supporting climate change education at the technical and vocational education level fulfill only 70 percent of the required standards. Similarly, higher education meets 70 percent, while teacher education training only fulfills 55 percent of the necessary requirements. This indicates that guidelines and training for teachers are still inadequate to provide sufficient exposure to climate change education.

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c) In a teacher survey conducted by UNESCO, almost 95 percent of teachers believed that teaching about climate change and its impacts is important or very important. However, less than 40 percent felt confident in teaching it, and only about one-third felt able to effectively explain the impacts of climate change on their local regions or communities.
d) Approximately 40 percent of teachers expressed confidence in teaching the cognitive dimension of climate change, but only about one-fifth were able to effectively explain how to take action.
e) Only 55 percent of teachers reported having received training—either pre-service or in-service—on climate change and sustainable lifestyles. Fewer than 50 percent reported that their schools have an action plan concerning climate change.

According to UNESCO (2020), as a recommendation through Education for Sustainable Development (ESD), to meet the growing educational needs in addressing increasing challenges, there must be a pedagogical framework that is action-oriented and innovative. This would enable students to develop knowledge and awareness, as well as take action to transform society towards a more harmonious and progressive life.

Therefore, innovation in education especially in the use of educational approaches geared toward sustainable development that can support climate change mitigation—is necessary. According to studies by Chin et al. (2019) and Sivapalan (2017), the use of blended learning approaches is considered appropriate, as blended learning provides flexible teaching and learning options for lecturers or teachers and students compared to traditional face-to-face approaches.

This is evident from the negative effects experienced by teachers during Home-Based Teaching and Learning (PdPR). According to a study by Mahalingam and Khairul Azhar (2021), teachers faced difficulties in preparing teaching materials suitable for students' competency levels during PdPR. Additionally, teachers struggled to integrate and adapt teaching and learning techniques and tools between face-to-face and online modes (Yang & Rao, 2022). This led to decreased student motivation and increased boredom (Platonova et al., 2022).

According to Bizami et al. (2022), there is a need to provide detailed guidelines on how to implement the cybergogy approach in teaching and learning processes, which would enable wider use of this pedagogy. Furthermore, the existing curriculum framework in Malaysia does not provide any guidelines on how to effectively use this pedagogy (Mahalingam & Khairul Azhar, 2021).

Transformative Learning Theory

This study is grounded in Transformative Learning Theory (TLT), as introduced by Mezirow (1997), which emphasizes that meaningful learning involves a deep, structural shift in the basic premises of thought, feelings, and actions. According to the theory, such transformation occurs when individuals engage in critical reflection on their existing assumptions and beliefs, particularly when confronted with experiences or information that challenge their existing worldview.

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In the context of Education for Sustainable Development (ESD), this theory is especially relevant. ESD is not only about acquiring knowledge on environmental or social issues but also about transforming the way individuals perceive their roles in creating a sustainable future. It encourages both learners and educators to reflect critically on values, habits, and systems that perpetuate unsustainable practices, and to adopt more holistic and forward-thinking worldviews (Cranton, 2006; Sterling, 2010).

Teachers play a pivotal role in this transformative process. Their perceptions, beliefs, and openness to change determine how they structure learning experiences in the classroom. Teachers who engage in transformative learning are more likely to adopt pedagogies that foster critical thinking, ethical responsibility, and sustainability awareness among students (Nolet, 2013). On the other hand, limited self-reflection or rigid adherence to conventional methods may result in superficial or fragmented integration of ESD content (Taylor, 2007).

Using Transformative Learning Theory as a guiding framework, this study aims to explore how STEM teachers' attitudes and perceptions towards sustainable development are constructed, challenged, and potentially transformed. The theory offers a useful analytical lens to investigate whether current teaching practices, professional development opportunities, and institutional contexts support the type of critical engagement and value-based reflection necessary for meaningful ESD integration in STEM classrooms.

Methodology

This study employed a descriptive quantitative approach using a survey questionnaire to assess the perceptions and attitudes of STEM teachers towards sustainable development. A total of 161 teachers from several secondary schools across the northern, central, eastern, and southern zones of Peninsular Malaysia were selected as the study sample.

The sample was chosen using cluster random sampling. This approach was adopted because the study population was geographically dispersed but shared homogeneous characteristics in terms of educational background and teaching experience in STEM subjects. According to Cross (2017), homogeneous cluster sampling is appropriate when the target groups possess similar criteria.

The research instrument consisted of a questionnaire adapted and modified from previous studies. The questionnaire underwent content validity review by subject matter experts and language specialists to ensure the suitability and clarity of the items. The instrument comprised three main sections:

a) Respondents' demographic information,
b) Items measuring the level of perception towards sustainable development, and
c) Items measuring attitudes towards sustainable development.

Data collected from the respondents were analyzed using the Statistical Package for the Social Sciences (SPSS) version 26.0. Descriptive statistics, including frequencies, percentages, mean scores, and standard deviations, were used to analyze the data. According to Sekaran (2000), descriptive statistics enable researchers to describe phenomena based on the patterns and distribution of data collected from respondents. The findings from this analysis were used to evaluate STEM teachers' knowledge and readiness regarding

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sustainable development issues within the Malaysian educational context.

Result

Demographics

The first section of the questionnaire gathered demographic information from 161 STEM teachers. This demographic analysis focused on four main aspects: age, educational level, ICT proficiency, and teaching experience in STEM subjects. A summary of the demographic profile of the respondents for Section A is presented in Table 2. The analysis revealed that the largest age group was between 41 and 50 years old (43.5%), followed by the 31 to 40 years age group (27.3%), and those aged 50 years and above (22.4%). The youngest group, aged 21 to 30 years, accounted for the smallest percentage at 6.6%.

Regarding educational level, the majority of respondents held a Bachelor's degree (80.7%), followed by a Master's degree (18.0%) and a Doctorate (1.2%). No respondents reported having a diploma qualification. In terms of ICT proficiency, most teachers rated themselves as having a good level of skills (54.0%), followed by moderate proficiency (34.8%), very good (8.7%), and weak skills (2.5%). Concerning teaching experience in STEM subjects, the majority of respondents had more than 10 years of experience (59.0%), followed by 6 to 10 years (20.5%), 1 to 5 years (18.6%), and less than 1 year (1.9%).

Table 2: Demographic Profile of Respondents (n = 161)

Demographic Profile	Category	Frequency (n)	Percentage (%)
Age	21–30 years	11	6.6
	31–40 years	44	27.3
	41–50 years	70	43.5
	50 years and above	36	22.4
Educational Level	Diploma	0	0.0
	Bachelor's Degree	130	80.7
	Master's Degree	29	18.0
	Doctorate	2	1.2
ICT Proficiency	Weak	4	2.5
	Moderate	56	34.8
	Good	87	54.0
	Very Good	14	8.7
STEM Teaching Experience	Less than 1 year	3	1.9
	1–5 years	30	18.6
	6–10 years	33	20.5
	More than 10 years	95	59.0

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STEM Teachers' Perception Levels Toward Sustainable Development

This section presents the analysis of research findings related to the perception levels of STEM teachers toward sustainable development. To assess the teachers' level of understanding, the mean scores of each item were analyzed and categorized into three levels: low, moderate, and high, as presented in Table 3.

Table 3: Mean Score Interpretation Table

Code	Range	Level
1	1.00 – 2.33	Low
2	2.34 – 3.67	Moderate
3	3.68 – 5.00	High

Source: Adapted from Wiersma, 2000

The analysis of ten items related to teacher perception revealed that overall, STEM teachers demonstrated a high level of perception toward sustainable development, with a mean score of 4.30 and a standard deviation of 0.640.

The highest mean scores were recorded for the following items:

- "*Biodiversity must be protected"* (M = 4.40, SD = 0.596)
- *"Reducing poverty is essential to ensure the economic well-being of the people"* (M = 4.40, SD = 0.595)

Meanwhile, the item with the lowest mean score, though still within the high category, was:

- "*People should make greater sacrifices to reduce economic disparities among populations"* (M = 3.94, SD = 0.927)

These findings suggest that STEM teachers have a positive perception of sustainable development across its three key dimensions: social, economic, and environmental.

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Table 4: Analysis of STEM Teachers' Perception Levels Toward Sustainable Development

No.	Item	Mean	SD	Level
1	Society should promote equal opportunities for both men and women	4.22	0.632	High
2	Relationships among different socio-cultural groups are important for society	4.25	0.602	High
3	Environmental disturbances often result in adverse effects	4.34	0.591	High
4	Environmental protection and human quality of life are directly interrelated	4.35	0.606	High
5	Biodiversity must be protected	4.40	0.596	High
6	Government economic policies should promote sustainable production	4.39	0.603	High
7	A country's policies should change if the nation is wasting its natural resources	4.35	0.596	High
8	People should make greater sacrifices to reduce economic disparities among populations	3.94	0.927	High
9	Reducing poverty is essential to ensure the economic well-being of the people	4.40	0.595	High
10	National policies should provide equal opportunities for economic development for all citizens	4.35	0.656	High
	Overall Mean	**4.30**	**0.640**	**High**

Source: Adapted from Balakrishnan et al. (2021)

STEM Teachers' Attitudes Toward Sustainable Development

Table 5 presents the analysis of 12 items related to STEM teachers' attitudes toward sustainable development. The analysis revealed that the overall level of attitude is high, with a mean score of 4.24 and a standard deviation of 0.716. The item with the highest mean score was:

> *"I am more aware that environmental protection is important for both the current and future generations"* (Mean = 4.36, SD = 0.694).

In contrast, the item with the lowest mean score, although still within the high category, was:

> *"I am more concerned that gender equality is important to society"* (Mean = 4.04, SD = 0.824).

These findings indicate that STEM teachers not only demonstrate a high level of awareness but also exhibit a strong attitudinal commitment towards the implementation of sustainable development principles within the educational context.

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Table 5: Analysis of STEM Teachers' Attitudes Toward Sustainable Development

No	Item	Mean	SD	Level
1	I am more aware that individuals should receive appropriate education that teaches them the knowledge, skills, and values needed for life.	4.29	0.720	High
2	I am more concerned that the current generation must ensure that future generations inherit good health, as we have today.	4.29	0.704	High
3	I am more concerned that gender equality is important to society.	4.04	0.824	High
4	I am more concerned about socio-cultural issues in my community.	4.20	0.660	High
5	I am more aware that environmental protection is important for both the current and future generations.	4.36	0.694	High
6	I am more concerned that biodiversity conservation is important.	4.34	0.670	High
7	I feel more responsible for protecting the environment and its resources.	4.32	0.648	High
8	I make more efforts and take appropriate actions to address the issue of global warming.	4.20	0.663	High
9	I am more concerned about the income gap between the rich and the poor.	4.13	0.743	High
10	I am more aware that equality is important for societal well-being.	4.14	0.746	High
11	The prices of basic necessities should be affordable for all income groups.	4.29	0.755	High
12	Economic opportunities should be accessible to everyone, regardless of their economic status.	4.22	0.766	High
	Overall Mean Score	4.24	0.716	High

Discussion

The findings of this study indicate that STEM teachers demonstrate a high level of perception and positive attitude towards sustainable development. These high mean scores reflect a strong understanding and support among teachers for the importance of sustainability within the education system, aligning with the global goals outlined in the Sustainable Development Goals (SDGs).

A high level of perception reflects teachers' awareness of critical global issues such as biodiversity conservation, poverty reduction, social justice, and sustainable economic policies. Meanwhile, their positive attitudes are evident through their commitment to environmental preservation, concern for income inequality, and support for equitable

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DOI: 10.55573/JISED.107306

economic opportunities within society. This demonstrates that teachers not only comprehend the concept of sustainable development at a theoretical level but are also supportive of its practical implementation in education.

These findings reinforce the view that teachers serve as vital agents of change in delivering sustainability-related values and principles to younger generations. In the context of STEM education, teachers who are knowledgeable and hold positive attitudes towards sustainable development are well-positioned to design and implement teaching strategies that promote sustainability-oriented thinking and practices. This is consistent with UNESCO's efforts to position education as a key medium for achieving the SDGs.

Nevertheless, UNESCO also highlights several challenges in the implementation of education for sustainable development (ESD), particularly concerning the lack of clear guidelines and pedagogical frameworks suitable for integration into everyday classroom practices. Therefore, this study underscores the need for a systematic and contextually appropriate framework aligned with national identity to ensure the effective integration of sustainability concepts into formal education.

This position is further supported by Kioupi and Voulvoulis (2019), who argue that there is a pressing need for a more detailed and contextualized curriculum adaptation based on the developmental stage and specific needs of each country. The education sector must be prioritised in driving this transformation, as it plays a fundamental role in shaping knowledgeable, responsible, and resilient societies capable of addressing future global challenges.

Conclusion

Overall, this study has demonstrated that the perception and attitudes of STEM teachers towards sustainable development are at a high level. These findings suggest that STEM teachers in Malaysia possess a strong awareness, sound knowledge, and positive attitudes regarding global sustainability issues. The results of this study may serve as a valuable reference for educational authorities, researchers, and policymakers in identifying appropriate pedagogical approaches, teaching strategies, and curriculum content that can strengthen teachers' understanding of sustainable development concepts. Such efforts are crucial in nurturing a generation of environmentally literate students who are socially, economically, and ecologically competent to face the challenges of an increasingly complex global landscape. By enhancing sustainability literacy among teachers, STEM education can serve as a foundational platform for ensuring environmental sustainability and global well-being in the future.

Acknowledgements

Praise be to Allah S.W.T, the Most Gracious and Most Merciful, for His blessings and guidance that have enabled me to complete this article. This endeavor would not have been possible without the support and contributions of several dedicated individuals who played a significant role behind the scenes throughout the research process. First and foremost, I would like to express my deepest appreciation and heartfelt gratitude to my supervisors, Dr. Haslinda Hashim and Associate Professor Dr. Jamilah Hamid, for their invaluable assistance, continuous guidance, and unwavering support throughout the implementation of this study.

Volume: 10 Issues: 73 [June, 2025] pp. 63 - 78
Journal of Islamic, Social, Economics and Development (JISED)
eISSN: 0128-1755
Journal website: www.academicinspired.com/jised
DOI: 10.55573/JISED.107306

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