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Research article

A needs analysis of humanizing STEM education through Scientist-Teacher-Student Partnership (STSP): Insights from science and humanities teachers

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Abstract: The global discourse on STEM education increasingly advocates integrating ethical, cultural, and social dimensions to ensure human-centered learning. Although the Scientist–Teacher–Student Partnership (STSP) has been proposed as a transformative approach to bridge disciplinary expertise and pedagogy, limited research has examined how teachers themselves conceptualize the need to humanize STEM in secondary education, particularly in the Malaysian context. To address this gap, this study adopted an interpretive qualitative design involving semi-structured interviews with 12 Malaysian secondary school teachers, comprising four science teachers and eight humanities teachers from History, Geography, Islamic Education, and Moral Education. Reflexive thematic analysis revealed three key themes: (1) Reconceptualizing STEM beyond technical knowledge, (2) strengthening teachers' support through partnerships, and (3) cultivating humanized STEM lessons. The findings reveal systemic and pedagogical barriers that constrain teachers' capacity to integrate moral, cultural, and contextual perspectives in STEM learning. By foregrounding teachers' voices, this study highlights the potential of the STSP framework as a collaborative platform to foster inquiry-based, ethically grounded, culturally and socially relevant STEM education. The study contributes to the global effort to re-envision STEM learning as a humanized, value-driven, and contextually responsive educational practice.

Keywords: humanizing STEM, scientist-teacher-student partnership (STSP), university-school partnership, STEM education, science education

1. Introduction

In an era characterized by rapid technological change, global sustainability challenges, and increasing calls for equity and inclusion in education, STEM (Science, technology, engineering, and mathematics) education has become not only a priority for workforce development but also a site for broader educational transformation. Many nations have framed STEM education as essential for developing human capital, innovation capacity, and global competitiveness [1,2]. STEM education has experienced rapid global advancement over recent decades, driven by evolving societal needs and strategic imperatives for talent development [3]. Simultaneously, the field has witnessed a marked transformation toward interdisciplinary collaboration, especially through the convergence of STEM with the humanities and social sciences [4]. There is a growing scholarly focus on broadening the traditional scope of STEM beyond its cognitive and technical dimensions by embedding humanistic perspectives within teaching and learning frameworks [5,6]. This integration fosters a richer, more inclusive paradigm of STEM education that values multiple epistemological standpoints and disciplinary interconnections [7]. The integration of the humanities into STEM is crucial, especially in addressing socio-scientific issues such as climate change and environmental pollution [8,9]. Through such interdisciplinary synthesis, educators are better equipped to cultivate students' holistic understanding of STEM, empowering them to respond ethically and contextually to complex, real-world challenges [6]. Current STEM education is often framed around content mastery, technical skills, innovation, and performance outcomes. While these dimensions are important, they may narrow students' understanding of science by underemphasizing ethical reasoning, cultural meaning, civic responsibility, and the social consequences of scientific and technological decisions. This creates a need to reconceptualize STEM education as a more human-centered practice that connects scientific learning with students' lived realities and responsibilities to society.

STEM education has traditionally emphasized the development of technical expertise and disciplinary knowledge [10–12], yet it often overlooks the ethical, social, and cultural dimensions that define learners as holistic human beings [13]. Although such dimensions are typically associated with the humanities, their inclusion in STEM is essential for cultivating a more comprehensive understanding of the world [5,7]. This study focuses on History, Geography, Islamic Education, and Moral Education, as these subjects are embedded in the Malaysian secondary curriculum and directly address ethical reasoning, cultural identity, civic responsibility, environmental awareness, and moral values. Moreover, integrating these subjects into the exploration of humanizing STEM enables a deeper understanding of how interdisciplinary connections can bridge cognitive and affective learning domains, nurturing students' ethical and contextual understanding of real-world issues [5,6,14]. Humanizing STEM is important because STEM education should not only develop technically competent learners but also nurture students who are ethically aware, socially responsible, culturally grounded, and capable of making decisions that affect human lives and the environment. In the context of secondary education, humanizing STEM may broaden students' participation by allowing learners from diverse cultural, disciplinary, and personal backgrounds to see STEM as meaningful to their identities, communities, and future responsibilities. Therefore, humanizing STEM has broader implications for equity, civic engagement, environmental responsibility, and the development of holistic learners who can connect scientific knowledge with social and moral consequences.

However, many students have limited exposure to ethical reasoning as an academic discipline, which constrains their ability to articulate moral standpoints or engage in thoughtful deliberation on scientific dilemmas [15]. Developing an informed and active citizenry, therefore, requires students to acquire analytical and critical thinking skills that enable ethical reasoning in addressing scientific and societal controversies [16]. Teachers play a crucial role in this process by nurturing students' decision-making capacities, encouraging openness to diverse perspectives, reducing biases, and facilitating constructive dialogue [17]. Through such pedagogical approaches, students are empowered to apply ethical reflection and critical judgment to navigate complex issues encountered in everyday life. In Malaysia, secondary education is guided by Malaysia's Secondary School Standard Curriculum (KSSM) and the Curriculum and Assessment Standards Document (DSKP), which emphasize not only disciplinary knowledge but also values, citizenship, sustainability, and cross-curricular elements. Science education provides students with scientific concepts, inquiry skills, and problem-solving practices, whereas humanities subjects such as History, Geography, Islamic Education, and Moral Education explicitly address cultural identity, civic responsibility, environmental awareness, moral reasoning, and universal values. This curricular structure provides an important context for exploring humanizing STEM by connecting STEM learning to ethical, cultural, national, and social dimensions already embedded in the Malaysian school curriculum.

The notion of humanizing STEM education seeks to address critiques that traditional STEM learning environments can be dehumanizing, treating students as passive recipients of knowledge, marginalizing their cultural and personal identities, and de-emphasizing the relational, contextual, and ethical dimensions of science and technology [6,14,15,18]. In this study, humanizing STEM refers to educational practices and learning environments that foreground humanity by integrating STEM and humanities perspectives. It emphasizes ethics, social responsibility, cultural relevance, students' voices, lived experiences, values, identities, and agency, while situating STEM learning in real-world contexts to promote inclusive, empowering, and equity-oriented outcomes. In turn, the term Scientist–Teacher–Student Partnership (STSP) refers to collaborative pedagogical relationships among practicing scientists, school teachers, and students in which all parties engage in mutual learning, dialogue, and co-construction of STEM-relevant tasks, thereby helping to bridge the gap between school STEM learning and authentic scientific practice [10,19]. For example, an implementation in Malaysia framed STSP as a collaboration among secondary students, teachers, and university scientists, encompassing mutual learning through a partnership [20–23]. The conceptual link between STSP and humanizing STEM lies in the capacity of partnership to transform STEM learning from a purely technical activity into a collaborative, dialogic, and socially situated practice. STSP provides opportunities for humanizing STEM by connecting teachers and students with authentic scientific expertise, supporting interdisciplinary dialogue, enabling co-construction of learning activities, and creating opportunities for ethical and contextual reflection. In this study, STSP is therefore positioned not merely as a support structure for STEM enrichment but as an operational mechanism through which humanizing STEM can be enacted in classroom practice.

Parallel to this, partnership models such as scientist–teacher collaborations, teacher professional learning communities, and student–faculty pedagogical partnerships have gained recognition as promising vehicles for bridging the school–science divide, enriching student experiences, and enabling more authentic STEM engagement [6]. Nevertheless, while much of the humanizing STEM research focus has been on higher education [5,6], less is known about how school-level STSP models can support humanizing STEM in secondary science education. Moreover, in a previous study, the need for humanizing STEM was from students' perspectives [23]; however, limited research has foregrounded teachers' interdisciplinary perspectives in conceptualizing humanizing STEM through a collaboration between science and humanities subjects. In sum, uncovering the needs, insights, and lived experiences of teachers and students is a timely endeavor that has implications for practice, policy, and theory. Therefore, this study centers on teachers' insights to explore their perceived needs for such humanizing partnerships. The theoretical point of departure is a humanizing pedagogy lens [24,25] combined with the STSP model [21]. Accordingly, the objective of this research is to explore the need for humanizing STEM through STSP from the perspectives of teachers in secondary schools.

2. Methodology

This study was guided by the following question: How do science and humanities teachers perceive the need for humanizing STEM through STSP in Malaysian secondary schools? This study adopted an interpretive qualitative design [26] to understand how individuals construct meaning from their experiences, practices, and social contexts. This design was appropriate because the study sought to explore how teachers interpret current STEM teaching practices and how they make sense of the need to integrate ethical, cultural, and social dimensions into STEM education. Rather than measuring outcomes, the study focused on teachers' meanings, perceptions, and reflections regarding humanizing STEM through STSP. This approach was deemed appropriate as it facilitates the exploration of rich, context-dependent insights that illuminate the complex, multifaceted nature of social interactions, human experiences, and pedagogical practices [27]. Qualitative inquiry enables researchers to understand how individuals construct meaning, interpret lived experiences, and engage with their learning environments [28]. Emphasizing context, experience, perspective, and subjectivity, this methodology offers a robust lens for examining the intricacies of educational phenomena [27]. Hence, exploring teachers' reflections on contemporary STEM instruction and their perceived need for more meaningful, human-centered educational practices was best approached qualitatively. Such inquiry yields nuanced and situated understandings that inform more contextually responsive pedagogical strategies. As Lim [27] asserted, qualitative research offers deep interpretive insights into experiences and interactions, ensuring a comprehensive understanding that can guide tailored educational interventions. Furthermore, this approach amplifies participants' voices, positioning teachers as active contributors within the STSP framework.

A purposive sampling strategy was employed to recruit information-rich participants [29]. The study involved 12 teachers from several secondary schools in Malaysia, comprising 4 science teachers and 8 humanities teachers specializing in History, Geography, Islamic Education, and Moral Education. The inclusion criteria required participants to possess a minimum of 10 years of teaching experience, as such individuals are considered experienced teachers, ensuring depth of expertise, aligning with criteria for experienced educators as defined by the Teaching and Learning International Survey (TALIS) [30]. Humanities teachers were additionally selected based on prior engagement in STEM-related programs or activities, ensuring their familiarity with interdisciplinary STEM learning contexts. These criteria ensured the selection of knowledgeable informants [31,32], capable of providing rich and relevant data. The sample size of 12 participants was considered sufficient because the participants were purposively selected as information-rich cases with substantial teaching experience and relevant exposure to STEM or interdisciplinary activities. During analysis, data saturation was assessed by monitoring the emergence of new codes and categories across transcripts [26,33]. Data collection and analysis indicated that no substantially new themes emerged in the later interviews, suggesting that the dataset was adequate to address the study's research question. The profiles of the participants are as follows:

Table 1. Details of the research participants.

Teacher	Subject	Years of teaching experience
ScT1	Science (General Science)	21
ScT2	Science (Physics)	32
ScT3	Science (Chemistry)	17
ScT4	Science (Biology)	19
HisT5	History	18
HisT6	History	10
GeoT7	Geography	20
GeoT8	Geography	10
IEdT9	Islamic Education	18
IEdT10	Islamic Education	10
MorT11	Moral Education	11
MorT12	Moral Education	10

The science teachers specialized in General Science, Physics, Chemistry, and Biology, while the humanities teachers taught History, Geography, Islamic Education, and Moral Education. Participants had prior exposure to STEM-related or interdisciplinary activities, which enabled them to provide informed reflections on the possibilities and challenges of humanizing STEM through partnership. Data were collected through one-to-one semi-structured interviews, guided by an interview protocol (refer to Table 2) that was peer-reviewed to ensure consistency while allowing flexibility to pursue emergent themes [26,27]. The interview protocol was peer-reviewed by two experts with experience in STEM education and qualitative research. The review focused on clarity, relevance, sequencing, and alignment of interview questions with the study objective [34]. Feedback from the review was used to refine the wording of questions and ensure that the protocol could elicit rich data on teachers' perceptions of humanizing STEM. Participants provided informed consent by signing the consent form prepared by the researchers prior to the interview sessions. The semi-structured format of the interviews enabled the researchers to pose follow-up questions based on participants' initial responses, allowing for deeper exploration and clarification of emerging responses [35].

Each session was scheduled according to participants' convenience and conducted over a three-week period. All interviews lasted 30–45 minutes and were audio-recorded and transcribed verbatim for analysis. Data were analyzed using reflexive thematic analysis [36] following the six-phase process: familiarization with the data, coding, generating initial themes, developing and reviewing themes, refining, defining, and naming themes, and writing up. The examples of reflexive thematic analysis conducted in this study are shown in Table 3.

Table 2. Participants' interview protocol.

No.	Interview question
1	How do you currently understand STEM education in your teaching practice?
2	In your experience, what aspects of current STEM teaching practices tend to emphasize technical knowledge or performance outcomes?
3	Do you think ethical, cultural, or social dimensions should be integrated into STEM education? Why or why not?
4	How can issues such as sustainability, environmental responsibility, or technological ethics (e.g., AI, robotics) be incorporated into STEM lessons?
5	In what ways can cultural values, local traditions, or national identity be connected to STEM learning?
6	What challenges do teachers face when trying to incorporate ethical or humanistic perspectives into STEM teaching?
7	What kinds of support or professional collaboration would help teachers implement humanizing STEM more effectively?
8	How could collaboration with scientists or experts from other disciplines contribute to more meaningful STEM learning experiences for students?
9	Can you describe examples of how STEM lessons could be connected to real-world community issues or local contexts?
10	In your opinion, what should a “humanized STEM lesson” look like in practice in secondary school classrooms?

Table 3. Examples of coding progress in theme 1 in this study.

Example of excerpt	Codes	Category	Theme
“The STEM subjects heavily focus on content mastery, performance, and scientific skills that are related to science. The most important thing is the science concept. The values and ethics are lacking in the implementation of science lessons. We do not have time for that.” (ScT1.ln.21-22)	Focus on content mastery	Technical orientation of STEM education	Theme 1: Reconceptualizing STEM beyond technical knowledge
“I train students to find solutions, build models, and relate them to scientific concepts, which are the most important things. I rarely ask who benefits or who might be harmed from the model that was built. But I think this one is also important too.” (ScT2.ln.15-17)	Limited attention to social impact		
“In science, particularly chemistry, we discuss plastics and polymers, but often overlook plastic waste. Students should recognize the moral responsibility tied to every experiment. They also	Moral responsibility in scientific practice	Integration of ethics and moral responsibility in STEM	

need to be aware of our national and global focus on sustainability, especially the SDGs (Sustainable Development Goals). It's not enough to excel academically and perform well. We need individuals who care about the environment and make ethical decisions when undertaking development projects." (ScT3.ln.25-28)		
"STEM today feels detached from moral formation. It builds skills, not soul." (MorT11.ln.17).	Detach from moral formation	
"STEM lacks integration of local tradition, heritage, and national identity. Patriotism should bring STEM and all the values together to shape well-rounded students." (HisT6.ln.13-14)	Integration of national identity and patriotism	Cultural and value-based dimensions of STEM
"In Islamic education, we teach amanah (trust) and khalifah (stewardship). STEM should carry these same principles when dealing with the environment." (MorT11.ln.22-23)	Islamic and religious values	

The analysis used an inductive coding approach, allowing codes to emerge from teachers' interview responses. These codes were then interpreted in relation to the study's conceptual concerns with humanizing STEM, ethical and cultural dimensions of STEM education, and the STSP framework. This approach enabled the analysis to remain grounded in participants' voices while also connecting the findings to the broader theoretical framing of the study. Data were collected over a three-week period from September 2024 to October 2024, based on participants' availability. The iterative process of data collection and analysis continued until data saturation was achieved [37–39].

Recognizing the critical role of validity and reliability in qualitative data analysis, the researchers employed investigator triangulation to enhance analytical rigor. The coding process involved two coders. Each coder independently read the interview transcripts and generated initial codes. The coders then compared their coding, discussed areas of disagreement, refined code definitions, and reached consensus through iterative discussion. Any differences in interpretation were resolved by returning to the original transcript excerpts and evaluating whether the codes accurately represented participants' meanings [34]. The cross-validation process among investigators ensured that the identified themes authentically reflected participants' perspectives and experiences [40,41]. Moreover, the high level of inter-coder agreement achieved during triangulation enhanced the dependability and confirmability of the coding framework, reducing subjective influence and promoting methodological transparency [42,43]. Through this rigorous process, the study achieved a high degree of credibility, trustworthiness, and analytical coherence, which are essential hallmarks of robust qualitative inquiry [31,32,44].

This study also employed reflexivity, as the researchers' backgrounds as lecturers and teachers in STEM education and Malaysian curriculum contexts informed the interpretation of teachers' perspectives. This familiarity supported a contextual understanding of STEM implementation, curriculum expectations, and the role of humanities subjects in Malaysian schools. At the same time, the researchers acknowledged that their prior interest in humanizing STEM and STSP could shape interpretation. To mitigate potential bias, the study employed reflexive discussion among researchers, investigator triangulation, repeated checking of codes against the transcripts, and documentation of analytic decisions throughout the thematic analysis process.

3. Findings

The findings reveal that science and humanities teachers perceived humanizing STEM as necessary for addressing the limitations of current STEM teaching practices. Teachers' responses showed that STEM education is often understood and implemented through technical knowledge, scientific performance, experimentation, innovation, and assessment outcomes. However, participants also emphasized that STEM learning should be connected to ethical reasoning, cultural identity, social responsibility, environmental awareness, and students' lived realities. Through thematic analysis, three major themes were identified: (1) Reconceptualizing STEM beyond technical knowledge, (2) strengthening teachers' support through partnerships, and (3) cultivating humanized STEM lessons. These themes explain how teachers conceptualized the need for humanizing STEM, the forms of support required to enact it, and the classroom practices through which it may be implemented. The themes, categories, and examples of codes emerging from the data are depicted in Table 4.

Table 4. Themes, categories, and examples of codes emerging from the data.

Theme	Category	Codes
1. Reconceptualizing STEM beyond technical knowledge	Technical orientation of STEM education	• Focus on content mastery • Limited attention to social impact • Limited time for ethical discussion • STEM treated as technical problem-solving
	Integration of ethics and moral responsibility in STEM	• Ethical implications of innovation • Moral responsibility in scientific practice • Responsible use of emerging technologies • Environmental ethics and sustainability awareness
	Cultural and value-based dimensions of STEM	• Detach from moral formation • Integration of national identity and patriotism • Islamic and religious values • Moral education and universal values • Character formation through STEM learning
2. Strengthening teachers' support through partnerships	Interdisciplinary collaboration in STEM education	• Collaboration between science and humanities teachers • Integration of multiple disciplinary perspectives • Curriculum alignment across subjects • Co-planning and co-teaching approaches
	Scientist–Teacher–Student Partnership (STSP) as	• Mentoring from scientists and humanities experts • Professional learning through collaboration

	professional support	• Partnership as a bridge between theory and practice
	Teacher empowerment through collaborative learning	• Increased confidence in implementing STEM • Reduction of professional isolation • Teachers becoming co-designers of learning • Shared inquiry and dialogic learning
3. Cultivating humanized STEM lessons	Contextualized STEM learning	• Linking science concepts to local issues • Integration of Malaysian environmental contexts • Community-based learning experiences
	Cultural heritage integration	• Incorporation of traditional knowledge • Appreciation of cultural heritage through STEM • Connecting history and science learning
	Socio-scientific and community-engaged STEM learning	• Addressing real-world issues • Collaboration with local agencies • Encouraging environmental stewardship and civic responsibility

Theme 1: Reconceptualizing STEM beyond technical knowledge

The first theme reflects teachers' shared view that STEM education should move beyond a narrow emphasis on technical knowledge, performance, and product-oriented innovation. Both science and humanities teachers described current STEM teaching as often focused on scientific concepts, experimentation, model-building, and achievement outcomes, while ethical, moral, cultural, and social dimensions are less explicitly addressed. This theme, therefore, captures teachers' call to reposition STEM as a more human-centered form of education that nurtures scientific understanding together with values, empathy, moral responsibility, and social consciousness. Science teachers acknowledged that their classroom practices frequently prioritized content mastery and scientific procedures over ethical reflection. One science teacher explained:

> *"The STEM subjects heavily focus on content mastery, performance, and scientific skills that are related to science. The most important thing is the science concept. The values and ethics are lacking in the implementation of science lessons. We do not have time for that."* (ScT1.ln.21-22)

Another science teacher similarly reflected that STEM problem-solving activities often focus on building solutions without sufficiently questioning their social consequences:

> *"I train students to find solutions, build models, and relate them to scientific concepts, which are the most important things. I rarely ask who benefits or who might be harmed from the model that was built. But I think this one is also important too."* (ScT2.ln.15-17)

Teachers also expressed concern that emerging technologies, such as robotics and artificial intelligence, are often treated as technical competitions rather than as opportunities for ethical and social reflection. As one science teacher noted:

> *"Nowadays, STEM is really close to the mounting use of technology, such as robotics. When I teach robotics or coding, most of the students treat it as a contest, not a contribution to*

> *society. The same goes for the usage of generative AI, students should know the ethics of using it."* (ScT3.ln.25-28)"

Humanities teachers deepened this critique by emphasizing the importance of moral formation, values, and national identity. A Moral Education teacher stated, *"STEM today feels detached from moral formation. It builds skills, not soul."* (MorT11.ln.17). Similarly, a History teacher highlighted the importance of connecting STEM with heritage, tradition, and national identity, *"STEM lacks integration of local tradition, heritage, and national identity. Patriotism should bring STEM and all the values together to shape well-rounded students."* (HisT6.ln.13-14)

Participants, therefore, perceived ethics and values as a missing dimension in STEM teaching and learning. They argued that scientific inquiry should not be detached from moral reflection, particularly when addressing issues such as sustainability, waste, and the consequences of innovation. One science teacher explained this point through the example of plastics and polymers:

> *"In science, particularly chemistry, we discuss plastics and polymers but often overlook plastic waste. Students should recognize the moral responsibility tied to every experiment. They also need to be aware of our national and global focus on sustainability, especially the SDGs (Sustainable Development Goals). It's not enough to excel academically and perform well. We need individuals who care about the environment and make ethical decisions when undertaking development projects."* (ScT3.ln.25-28)

A humanities teacher made a similar point by connecting STEM learning with national and global sustainability goals:

> *"Their responsibility extends to plastic use in daily life. They should also be aware of the national and global goals, such as the aim for zero single-use plastic by 2030. Therefore, they need to understand their role in achieving these objectives. I believe this should be part of STEM learning to make it more inclusive, covering not just theories or scientific concepts but also how these relate to society, our nation, and the world."* (GeoT8.ln.29-36)

Religious and moral values were also viewed as resources for humanizing STEM. An Islamic Education teacher explained how the concepts of trust and stewardship could guide STEM learning: *"In Islamic education, we teach amanah (trust) and khalifah (stewardship). STEM should carry these same principles when dealing with the environment."* (MorT11.ln.22-23). A Moral Education teacher also emphasized the role of universal values and social responsibility in shaping future citizens:

> *"In moral education, we also emphasize social responsibility towards society in all aspects of our daily activities. Additionally, we recognize 18 universal values that students are required to practice daily. It is essential to cultivate students who are not only intelligent and clever but also morally upright, thereby fostering high-quality future individuals with strong human capabilities."* (MorT12.ln.28-31)

Teachers further explained that STEM becomes more meaningful when scientific concepts are connected to local issues and community realities. For instance, one science teacher described how calculating carbon emissions helped students understand the social and environmental relevance of science:

> *"When my students calculated CO_2 emissions from cars in our town, they realized science can protect the earth, not just describe it. They recognized their role in lowering carbon emissions to address climate change, which impacts us nowadays. They also realized their role in the community."* (ScT1.ln.33-36)

A History teacher also showed how historical and cultural contexts could enrich STEM learning:

> *"When students study the Sultanate of Malacca, they explore its rich history, the port, and the golden age of Malacca, while also seeing how geography, science, and ethics are intertwined. This approach humanizes knowledge. The goal is to prepare a future global citizen who is equipped to address pressing worldwide challenges."* (HisT6.ln.22-25)

Overall, this theme shows that teachers perceived current STEM education as insufficient when it is limited to technical mastery. From their perspectives, humanizing STEM begins with reconceptualizing it as a moral, cultural, social, and environmentally responsible form of learning. Teachers emphasized that students should not only understand scientific concepts but also examine the ethical consequences and human purposes of scientific knowledge.

Theme 2: Strengthening teachers' support through partnerships

The second theme focuses on the support structures teachers considered necessary for enacting humanizing STEM in practice. While teachers valued integrating ethics, culture, and social responsibility, several participants indicated they needed professional support, interdisciplinary collaboration, and access to expertise to implement these approaches effectively. In this regard, the Scientist–Teacher–Student Partnership (STSP) was viewed as a practical mechanism for supporting teachers through mentoring, co-planning, authentic scientific engagement, and interdisciplinary dialogue. Some teachers recognized that humanizing STEM requires guidance not only from scientists but also from humanities experts who can support its ethical, cultural, and moral dimensions. One science teacher explained:

> *"Since I think ethics and values are important in STEM learning, other than a scientist, I also need guidance from the humanities sciences to learn more about the humanities aspect in implementing STEM learning. The inclusion of humanities scientists can make the understanding better. The scientists can focus on the scientific part, while the humanities scientists can contribute to the humanities aspect, such as ethical and moral decisions."* (ScT1.ln.21-22)

Teachers also identified opportunities for cross-disciplinary alignment within the Malaysian curriculum. A Geography teacher described how science and geography topics could complement one another, particularly in relation to environmental issues:

> *"Reviewing the DSKP (Curriculum and Assessment Standards Document), we find that certain science topics align closely with geography, especially environmental issues and their management. Science classes typically cover critical concepts related to climate change and global warming, while geography emphasizes strategies for managing these issues. This provides a broader, more comprehensive perspective on the topic within a global context."* (GeoT7.ln.33-37)

Another Geography teacher connected this interdisciplinary potential with national environmental policy and sustainability goals:

> *"In geography, we also highlight actions related to environmental quality. In Malaysia, this is exemplified by Act 127, the Environmental Quality Act of 1974, which is the primary law aimed at preventing, controlling, and eradicating pollution while conserving the environment. The Act has been amended and enforced to promote environmental sustainability, aligned with the Shared Prosperity Vision 2030 and the Sustainable Development Goals (SDG). The recent amendment in 2024 increased fines and penalties, including fines up to RM10 million and mandatory imprisonment for certain offenses. Emphasizing these aspects is crucial in STEM learning to foster collaboration and make the learning experience more meaningful."* (GeoT8.ln.29-36)

Participants further envisioned interdisciplinary co-planning and co-teaching as ways to support humanized STEM lessons. One science teacher stated:

> *"To humanize STEM, collaboration between STEM and humanities is essential for creating a more comprehensive learning experience. We can co-create and co-plan learning contexts that extend beyond STEM knowledge to include humanities. Additionally, scientists can serve as mentors to teachers, helping them update their skills and knowledge."* (ScT3.ln.25-28)

A Moral Education teacher added that collaboration with scientists and humanities experts could make classroom discussions more authentic and meaningful for students:

> *"Working with scientists and humanities experts as co-mentors makes discussions more tangible, as students interact with authentic specialists committed to ethics rather than simply facts. This setup appears mutually advantageous, as scientists also receive insights into modern teaching methods. Additionally, students greatly benefited from this collaboration."* (MorT12.ln.28-31)

Teachers also explained that partnership experiences could increase their confidence and reduce professional isolation. One teacher reflected:

> *"Working with scientists has boosted my confidence in guiding research projects; previously, I felt isolated when teaching complex experiments. As I have experience in partnership before, I think with support from scientists, I feel more confident in my teaching."* (ScT2 ln. 15-17)

Overall, this theme shows that teachers viewed partnerships as an enabling structure for humanizing STEM. The STSP model was perceived as a way to strengthen teachers' confidence, provide access to scientific and humanistic expertise, support interdisciplinary collaboration, and help translate humanizing STEM aspirations into classroom practice.

Theme 3: Cultivating humanized STEM lessons

The third theme focuses on how teachers envisioned humanizing STEM at the classroom level. Participants described humanized STEM lessons as lessons that connect scientific ideas with students' lived experiences, local issues, cultural heritage, community concerns, and environmental responsibilities. Rather than treating contextualization as an additional activity, teachers viewed it as central to making STEM meaningful and socially responsive. They emphasized that Malaysian environmental issues, traditional knowledge, waste management, carbon emissions, and cultural craftsmanship could serve as authentic contexts for humanized STEM learning. A History teacher illustrated this idea by explaining how traditional knowledge and environmental concerns could be integrated through the example of natural dyes and batik:

> *"We explore the historical use of natural dyes in Malay culture to help students appreciate both tradition and innovation. Today, chemical dyes largely harm our environment and water systems, as seen in Kelantan. However, through STEM, we can develop eco-friendly dyes that protect our environment. By doing so, we honor our cultural heritage, including batik, while also ensuring its preservation."* (HisT4.ln.24-28)

Teachers also emphasized the importance of linking STEM lessons with real-world community issues and local agencies. One participant explained how waste management could become a meaningful context for STEM problem-solving:

> *"We can humanize STEM education by integrating local contexts like waste management. Collaborating with local agencies such as the Solid Waste and Public Cleansing Management Corporation (SWCorp) can help students connect with real-world issues. For example, exposing students to data showing plastic is the second-largest waste after food waste prompts them to consider solutions. They might think about composting food waste to create fertilizer or inventing bioplastics from food waste to address plastic pollution, too."* (ScT1.ln.21-22)

Another teacher described waste management as both a scientific and civic issue that students need to understand in everyday life:

> *"Our discussion on solid waste highlighted it as a major issue, particularly waste management itself. When asked how many students know how to handle their waste or what types go into the SWCorp bin, most are unsure. This indicates a need for education not just about the concepts but also about their real-life applications. For instance, in Germany, waste management is included in geography textbooks, and even plastic bottles can be recycled for cash. In Malaysia, the SWCorp was established to support the National Solid Waste Management Policy under Act 672. We must take action; if not us, then who?"* (GeoT7.ln.33-37)

Teachers also connected humanizing STEM with socio-scientific inquiry related to climate change and carbon emissions. One teacher explained:

> *"One of the main issues today is carbon emissions. We can teach students, for instance, in science classes, about processes like photosynthesis. We need oxygen to survive and produce carbon dioxide, which raises the question: why shouldn't we cut down trees and instead plant more? How much CO_2 can a tree store? Students have a responsibility to reduce their carbon footprint. These scientific concerns affect society and are known as socio-scientific issues. Addressing these challenges is essential."* (ScT4.ln.25-28)

Overall, this theme demonstrates that teachers understood humanized STEM lessons as contextualized, value-driven, and community-connected. Teachers emphasized that STEM learning should be grounded in local Malaysian realities, environmental concerns, cultural heritage, and students' daily lives. Through such lessons, students may come to see science not only as abstract knowledge but as a means of contributing to society, protecting the environment, and valuing cultural identity.

4. Discussion

The findings of this study show that teachers conceptualized humanizing STEM as a necessary response to the technical and performance-oriented tendencies of current STEM education. Across science and humanities perspectives, participants argued that STEM learning should not be limited to the mastery of scientific concepts, experimentation, innovation, or assessment outcomes. Instead, they emphasized that STEM should be connected to ethical reasoning, moral responsibility, cultural meaning, civic awareness, and environmental stewardship. This suggests that humanizing STEM is not merely an instructional strategy but a broader pedagogical reorientation that reframes science education as a human, social, and value-laden practice.

Humanizing STEM as a response to technical and amoral STEM education

The first theme indicates that teachers perceived a gap between technical STEM learning and the broader human purposes of education. Their reflections suggest that STEM education may become decontextualized when students are trained to solve problems, build models, or use emerging technologies without asking ethical questions about benefits, harms, responsibility, and societal consequences. Collectively, these reflections affirm the teachers' conviction that STEM education must evolve from a purely cognitive, skills-based approach to a morally conscious, culturally grounded, and socially responsible practice. Teachers' reflections reveal an emerging philosophical and pedagogical reorientation from teaching science as a neutral body of facts toward teaching science as a human practice situated within social, cultural, and moral contexts. This shift mirrors a global movement toward humanizing STEM education, which calls for integrating empathy, ethical reasoning, and social responsibility into scientific learning [5,6,14].

The teachers' insights echo what Yao et al. [14] described as an ecological systems approach to humanizing STEM, in which learners are encouraged to engage critically with scientific knowledge and its implications for communities and ecosystems. Similarly, Azizi et al. [5] argued that humanizing STEM requires an intentional redesign of curricula to develop "the whole person": not merely technically adept individuals, but citizens capable of moral judgment and social empathy. This resonates strongly with the teachers' recognition that STEM lessons often overlook moral formation, as well as local cultural heritage and values that shape learners' sense of identity and purpose.

The teachers' concerns also align with Freire's humanizing pedagogy [24]; the teachers' critique of technical STEM can be understood as a concern with the decontextualization of knowledge. A STEM curriculum that treats science as neutral, amoral, and disconnected from social realities may limit students' opportunities to question who benefits from scientific innovation, who may be harmed, and how scientific decisions relate to power, justice, and community wellbeing. In this sense, the teachers' call to STEM to include Islamic values [45], such as trust and stewardship in STEM practice, moral values, and cultural relevance, signifies an epistemological expansion framing scientific inquiry as a moral and spiritual act of responsibility toward both humanity and the environment. Integrating these ethical and cultural dimensions into STEM learning may help students see science not only as a tool for innovation but also as a means for societal betterment and environmental care. Therefore, humanizing STEM involves more than adding values to science lessons; it requires cultivating critical consciousness by enabling students to examine the ethical, social, and environmental consequences of STEM knowledge and to imagine more responsible forms of scientific practice. This deepens the study's theoretical contribution by connecting teachers' practical concerns with a critical, humanizing understanding of STEM education.

STSP as an operational mechanism for humanizing STEM

The second theme extends the discussion by showing that teachers did not view humanizing STEM as achievable solely by individual teachers. Instead, they emphasized the need for partnership, mentoring, interdisciplinary collaboration, and professional support. This finding positions the Scientist–Teacher–Student Partnership (STSP) as an operational mechanism for humanizing STEM. Through STSP, teachers can access authentic scientific expertise, collaborate across disciplinary boundaries, and design learning activities that connect scientific concepts with ethical, cultural, and social considerations. These findings align with recent literature showing STSP as a scientist–school collaboration that enhances teacher efficacy, inquiry confidence, and instructional authenticity [22,46,47]. Such partnerships reframe teachers not as implementers of externally designed curricula but as co-designers of knowledge, an essential element of humanizing pedagogy [5]. Moreover, teachers viewed the partnership as mutually beneficial: scientists gained pedagogical awareness while teachers developed scientific authenticity and moral contextualization [21].

This study, therefore, extends existing STSP scholarship by showing that this partnership can do more than enhance scientific authenticity or support inquiry-based learning. When expanded to include humanities perspectives, STSP can also support ethical deliberation, cultural contextualization, and values-based STEM learning [23]. Scientists may contribute with disciplinary depth and authentic scientific practice, while humanities educators may contribute with perspectives on morality, citizenship, culture, religion, environmental responsibility, and social implications. Teachers, in turn, become co-designers rather than passive implementers of STEM activities. This reciprocal structure reflects a dialogic model of professional learning in which knowledge is co-constructed among scientists, teachers, and students. In this way, STSP provides a practical pathway for translating humanizing STEM from a conceptual aspiration into classroom-based curriculum practice.

Malaysian curriculum and cultural context as a site for contextualized STEM learning

The third theme highlights the importance of local context in the enactment of humanizing STEM. Teachers proposed that STEM lessons could be made more meaningful by connecting science with Malaysian environmental issues, cultural heritage, traditional knowledge, sustainability policies, waste management, carbon emissions, and community-based problems. This finding suggests that humanized STEM is strongly place-based: it becomes visible when scientific inquiry is situated within the ecological, cultural, civic, and moral realities that students encounter in their daily lives. The Malaysian context is particularly significant because humanities subjects such as History, Geography, Islamic Education, and Moral Education already address values, citizenship, environmental awareness, identity, and moral reasoning within the secondary curriculum. The findings, therefore, show that humanizing STEM can be supported by existing curricular resources rather than treated as an external addition to science education.

5. Implications of the study

This study has several implications for STEM education practice and policy. By connecting science with humanities subjects, teachers can help students understand STEM knowledge in relation to cultural identity, environmental stewardship, religious and moral values, national responsibility, and global sustainability. This contributes to the literature by offering perspectives from other countries on humanizing STEM, in which ethical, cultural, and civic dimensions are embedded in the curriculum and broader educational aims. Overall, this theme reveals that teachers conceive humanizing STEM as an act of localization, situating scientific inquiry within Malaysia's ecological, social, and cultural realities. Such contextualization aligns with current research emphasizing that meaningful STEM learning must be situated in place-based, value-driven, and community-based contexts [4,6,14]. This is also in line with studies highlighting the importance of culture and indigenous knowledge in STEM lessons [48–51]. Through contextualized pedagogy, students not only master scientific knowledge but also develop ethical consciousness, environmental empathy, and cultural pride, hallmarks of the humanized STEM paradigm [52].

At the policy level, humanizing STEM through STSP requires structural support rather than relying solely on individual teacher initiative. STEM education policies should explicitly support interdisciplinary collaboration between science and humanities subjects, particularly when curriculum standards already emphasize values, citizenship, sustainability, and cross-curricular learning. Policy guidance may also encourage schools to recognize STSP as a professional and pedagogical model that connects scientific expertise, teacher knowledge, student voice, and community-based issues. Such support could help shift STEM education from a predominantly technical and performance-oriented agenda toward a more ethical, culturally responsive, and socially responsible educational practice.

At the school level, administrators play an important role in reducing barriers to STSP implementation. Administrators can promote STSP by allocating common planning time for science and humanities teachers, providing flexibility in school timetables or bell schedules for interdisciplinary activities, and supporting professional development focused on ethical, cultural, and community-based STEM learning. Schools may also appoint a partnership coordinator or STEM committee to connect teachers with scientists, humanities experts, universities, and local agencies. These forms of administrative support are important because teachers in this study perceived partnership, mentoring, and co-planning as necessary conditions for translating humanizing STEM from an aspiration into classroom practice.

Students should also be positioned as active participants in STSP rather than as passive recipients of STEM activities. Within humanizing STEM, students can contribute by identifying local socio-scientific issues, asking ethical questions, engaging in community-based inquiry, and reflecting on how STEM decisions affect people, culture, and the environment. Student voice can be incorporated through reflective journals, classroom dialogue, project presentations, and participatory decision-making during STEM investigations. In this way, STSP can support students not only in learning scientific concepts but also in developing agency, civic responsibility, and ethical awareness.

6. Limitations and recommendations for future studies

This study has several limitations that should be considered. First, the humanities perspectives included in this study were confined to History, Geography, Islamic Education, and Moral Education. Although these subjects offered relevant ethical, cultural, civic, and social insights into humanizing STEM within the Malaysian secondary school context, they do not represent the broader spectrum of humanities disciplines that could further strengthen interdisciplinary STEM learning, such as language studies, literature, and philosophy. Future studies may therefore involve a broader range of humanities disciplines to provide a more comprehensive understanding of how humanistic knowledge can be integrated into STEM education.

Second, this study involved a small, purposively selected group of 12 teachers; therefore, the findings should not be interpreted as representative of the wider population of science and humanities educators. The enactment of humanizing STEM through STSP may require broader educator buy-in, sustained professional development, and school-level support before it can be implemented more widely. Third, this study focused on teachers' perspectives because teachers are key actors in planning, designing, and enacting pedagogical approaches within the STSP framework. Their perspectives are important as they influence curriculum interpretation, instructional decision-making, classroom practices, and the structure of partnerships that shape students' learning experiences. Future studies could also examine how administrators, scientists, humanities experts, and community partners contribute to sustaining STSP in different educational settings. Comparative studies across different school systems may further clarify how humanizing STEM can be adapted according to local curriculum structures, cultural contexts, and partnership infrastructures.

7. Conclusions

This study explored teachers' perspectives on the need for humanizing STEM through the Scientist–Teacher–Student Partnership. The findings show that teachers viewed humanizing STEM as necessary to move beyond technical, performance-oriented STEM learning toward a more ethical, culturally responsive, socially responsible, and contextually meaningful form of education. By foregrounding the perspectives of both science and humanities teachers, this study extends discussions of humanizing STEM into secondary education and highlights the importance of interdisciplinary teacher voice in shaping STEM reform. The study also positions STSP as a promising collaborative structure for supporting teachers in designing STEM learning that connects scientific concepts with ethical reasoning, cultural identity, community issues, and students' lived realities. Rather than treating humanizing STEM as an abstract ideal, the findings suggest that it can be enacted through sustained partnerships, administrative support, teacher professional learning, and student participation. In this sense, humanizing STEM through STSP offers a pathway for reimagining STEM education as a more inclusive, value-driven, and socially responsive educational practice.

Author contributions

Napisah Yahya: Conceptualization, methodology, investigation, data curation, analysis, writing - original draft, writing- review and editing. Hidayah Mohd Fadzil: Conceptualization, supervision, methodology, validation, writing- review and editing. Mohd Nor Syahrir Abdullah: Supervision, validation, writing- review, and editing. All authors have read and approved the final version of the manuscript for publication.

Use of Generative-AI tools declaration

This manuscript involved the use of ChatGPT (OpenAI, GPT-5.1) to support language refinement, grammar improvement, and enhancement of clarity in several sections of the paper. The tool was not used to generate research data, analyze data, interpret findings, or draw conclusions. All ideas, conceptual development, methodological decisions, and interpretations were entirely produced by the authors. The use of ChatGPT was limited to editorial assistance only, and all outputs were thoroughly reviewed, verified, and edited by the authors to ensure accuracy and alignment with the study's intended meaning.

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Conflict of interest

The authors declare that there are no conflicts of interest.

Ethics declaration

The ethical approval was obtained from the Universiti Malaya Research Ethics Committee (UM.TNC2/UMREC_3853) and approved by the Educational Policy Planning and Research Division of the Ministry of Education Malaysia (KPM.600-3/2/3-eras(21142)). All participants were given consent to participate in this study.

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