STUDENTS' INSIGHTS ON STEM LEARNING: NEEDS ANALYSIS OF HUMANIZING STEM THROUGH SCIENTIST-TEACHER-STUDENT PARTNERSHIPS (STSP)

Napisah Yahya[1]
*Mohd Nor Shahrir Abdullah[1]
Hidayah Mohd Fadzil[1]

[1] Department of Mathematics and Science Education, Faculty of Education, University Malaya, Kuala Lumpur, Malaysia

*mnsyahrir@um.edu.my

ABSTRACT

The global discourse on STEM education is increasingly emphasizing the need to integrate ethical, social, and cultural dimensions to ensure that learning is both technologically relevant and human-centered. While the Scientist-Teacher-Student Partnership (STSP) has been recognized as a promising model for bridging expertise and pedagogy, limited attention has been paid to how secondary school students themselves perceive the need for humanizing STEM learning. This study employs a basic interpretive qualitative design to capture insights from five (5) Malaysian upper-secondary students in the STEM stream through semi-structured interviews. Based on the thematic analysis, three (3) themes have emerged, which are (1) issues in STEM learning, (2) instructional strategy in STEM lessons, and (3) elements needed in humanizing STEM lessons. However, this paper will only discuss the first theme on the issues in STEM learning, which consists of three (3) categories, namely, (1) limited opportunities for inquiry and authentic practical engagement, (2) oversight of ethical, social, and cultural perspectives in STEM lessons, and (3) fragmented and siloed curricula that restrict interdisciplinary connections. These findings highlight systemic and pedagogical gaps that constrain student engagement and diminish the transformative potential of STEM education. By foregrounding student voices, the study emphasises the importance of humanizing STEM through STSP, where scientists, including humanities scientists, teachers, and students, reframe learning collaboratively, becoming inquiry-driven, ethically grounded, and socially relevant. The findings provide a needs analysis to inform the design of humanizing STEM modules and STSP-based interventions in secondary schools, with implications for curriculum reform, teacher professional development, and sustainable partnerships between scientists and schools.

Keywords: *Humanizing STEM, Scientist-Teacher-Student Partnership (STSP), partnership, STEM education, teaching and learning.*

INTRODUCTION

In recent years, global discourse regarding Science, Technology, Engineering, and Mathematics (STEM) education has underscored its significance in preparing learners with 21st-century competencies, critical thinking skills, and problem-solving abilities essential for tackling complex global challenges such as climate change and food security. While the STEM agenda has successfully advanced technological and economic priorities, it has been critiqued for frequently overlooking the human aspects of learning. A lack of humanities in STEM education leads to a fragmented and less holistic approach to problem-solving, resulting in technology that may not be human-centred, ethical, or socially beneficial (Faulconer et al., 2020). It also risks creating a generation of technically skilled individuals lacking the critical thinking, empathy, and creativity fostered by the humanities, which are essential for innovation and

addressing complex, real-world challenges effectively (Edwards & Ritchie, 2022). The absence of humanistic insight in STEM learning leads to a disconnect, which may result in students having a narrow perspective on STEM (Tan et al., 2024), solely focusing on the technical aspects while frequently overlooking the important ethical, social, and cultural aspects of STEM learning.

Humanities disciplines foster critical thinking, ethical reasoning, and a deeper understanding of the human condition, all essential for navigating the complexities of modern life (Edwards & Ritchie, 2022). The integration of STEM and humanities is crucial in addressing socio-scientific issues (SSI) (Macalalag et al., 2024; Ozturk & Roehrig, 2025; Tang et al., 2024; Wahono et al., 2021). The United Nations Educational, Scientific, and Cultural Organization (UNESCO) highlights the necessity of broadening students' competencies to encompass not only cognitive skills but also social and emotional skills (UNESCO, 2022). This perspective aligns with the 2027 School Curriculum introduced by the Malaysian Ministry of Education (MOE), which aims to cultivate individuals capable of leading balanced lives. The curriculum emphasizes personal development, communication, responsibility, digital fluency, diverse literacy, critical thinking skills, and lifelong learning (Ministry of Education, 2025). Furthermore, it prioritizes character formation and value-based education across various subjects, tailored to the specific levels of each school.

In light of this, STEM education has evolved to foster increased interdisciplinary collaboration by integrating the humanities and social sciences with STEM. This integration has brought about significant transformations and enhancements within the STEM field (Zhan & Niu, 2023). There has been a growing notion to broaden STEM's focus beyond its cognitive and technical domains, calling to humanise STEM education (Azizi et al., 2023; Cook-Sather et al., 2023; Hendrickson & Blackmon, 2025; Yao et al., 2023). Humanising STEM highlights the integration of STEM and humanities fields, bringing a more diverse and inclusive approach to STEM education by integrating a more comprehensive range of perspectives and disciplines (Imad et al., 2023). The interdisciplinary approach helps teachers to educate students towards shaping a more holistic understanding of the field, in preparing them to address complex, real-world problems innovatively and effectively (Cook-Sather et al., 2023). Humanizing STEM is not merely about making content relatable but about re-envisioning instruction to bridge cognitive, affective, and moral dimensions of learning.

Traditionally, STEM education mainly focuses on technical skills and knowledge (Ismail et al., 2022; Roehrig et al., 2021; Shahali & Halim, 2024; Tytler et al., 2023), often lacking integration of ethics, social responsibility, and cultural relevance of students as human beings in STEM learning (Imad, 2020). These concepts and ideas, which may seem to be the purview of the humanities, are essential in STEM because they promote a more holistic understanding of the world around us (Azizi et al., 2023; Cook-Sather et al., 2023; Imad et al., 2023). Many students lack familiarity with ethics as a discipline, which hinders their ability to articulate their stance or engage in reasoned discussions about ethical issues in science (Chowdhury, 2016; Kreth et al., 2024).

Malaysia has articulated clear national aspirations for a more holistic, future-ready STEM education ecosystem. The philosophy of education in Malaysia aims to develop individuals holistically, intellectually, spiritually, emotionally, and physically, based on a belief in God. The National Philosophy of Education seeks to produce knowledgeable, morally upright, and responsible citizens who are unified and contribute to the betterment of their families, society, and nation, as stated by the Education Act (1996) (Commissioner of Law Revision Malaysia, 2012). The National Philosophy of Science Education (MOSTI, 2013) also aims to cultivate a culture of science and technology by focusing on developing competitive, dynamic, resilient individuals who can master scientific knowledge and technological skills. This philosophy aligns with the broader National Philosophy of Education, emphasizing holistic development. In line with current needs, the 2027 School Curriculum Reform recently positions "humanizing education" and "character education" as a guiding philosophy, emphasising students' socio-emotional development, ethical reasoning, and connection to community challenges (Ministry of Education, 2025). These policy directions align with global discourses that call for a shift towards socially responsive and value-laden STEM learning. Nevertheless, evidence suggests that classroom implementation continues to prioritise exam-oriented, teacher-centred, and discipline-isolated practices, limiting opportunities for

students to experience STEM as meaningful, human-centred learning. This policy practice tension underscores the need for empirical studies that capture students' lived experiences and identify specific gaps that humanizing STEM approaches, such as the Scientist-Teacher-Student Partnership (STSP), can address.

To nurture an active, informed citizen, students acquire analytical and critical thinking skills to utilize ethical reasoning when addressing scientific controversies (Chowdhury et al., 2020). Educators are tasked with not only nurturing students' decision-making abilities but also guiding them to respectfully consider different viewpoints, overcome prejudices, and effectively communicate their dissenting opinions (Isma'il et al., 2021). This educational approach empowers students to apply ethical reflection and critical thinking to navigate challenging situations in their daily lives. Furthermore, STEM curricula often neglect cultural contexts and indigenous knowledge (Sumarni et al., 2020, 2023), potentially alienating students from diverse backgrounds and limiting the applicability of scientific knowledge to local contexts. Integrating cultural aspects into STEM education can enhance inclusivity and relevance, cultivating a stronger sense of belonging and engagement among students from diverse cultural backgrounds (Primadianningsih et al., 2023).

One promising pathway toward humanizing STEM is through the Scientist-Teacher-Student Partnership (STSP) model, which situates collaboration at the heart of learning and highlights the collaboration factors between the teachers, scientists, and students. Unlike traditional outreach approaches, STSP emphasizes reciprocal exchange between scientists, teachers, and students, fostering authenticity and inquiry (Saat et al., 2021, 2023; Yahya et al., 2025). Scientists contribute disciplinary expertise, teachers translate content into pedagogically sound practices, and students engage as active investigators in meaningful contexts. Nevertheless, the prevailing STSP efforts often fall short in bridging STEM and humanities in secondary science learning (Fadzil et al., 2019; Ismail, Fadzil, et al., 2022).

However, despite the humanized potential of STEM, little is known about how secondary school students themselves perceive the need for humanizing STEM learning through STSP. Existing humanizing STEM studies have predominantly centred on tertiary-level education (Azizi et al., 2023; Cook-Sather et al., 2023; Hendrickson & Blackmon, 2025; Yao et al., 2023), leaving a significant gap in implementation in secondary school. In the Malaysian context, the MOE officially classifies Geography, History, Islamic, and Moral Education under the domain of the humanities field in the Curriculum and Assessment Standard Document (DSKP) or for the Secondary School Standard Curriculum (KSSM) (MOE, 2017). For official curricular purposes, therefore, in this study, the term *humanities* is used precisely, even though in the wider global academic discourse, these subjects are frequently categorized under the *social sciences*. Capturing students' insights is critical, as they are the direct beneficiaries and active participants whose engagement, motivation, and identity formation determine the success of STEM education reforms (Eccles & Wigfield, 2020; Masson et al., 2016). A needs analysis grounded in students' perspectives, therefore, provides a foundation for designing pedagogical approaches that are contextually aligned, ethically grounded, and aligned with learners' aspirations.

Despite the growing research on STEM integration and STSP in Malaysia (e.g., Fadzil et al., 2019; Ismail et al., 2022), prior studies have primarily focused on students' general perceptions of STEM lessons and integrated STEM instructional practices, without explicitly foregrounding the ethical, social, and cultural dimensions that underpin humanizing STEM. Moreover, existing STSP research has tended to emphasise teachers' professional development and integrated STEM design, with comparatively less attention to how secondary school students themselves conceptualise the need for humanizing STEM learning through partnerships that include humanities disciplines. This reveals a conceptual and empirical gap concerning students' voices in articulating what a humanized STEM experience should look like within the STSP framework. This study extends earlier STSP work in Malaysia by foregrounding students' voices on humanizing STEM. It surfaces how students perceive gaps related to inquiry opportunities, ethical and cultural perspectives, and interdisciplinary connections, thereby sharpening the conceptualisation of humanizing STEM at the secondary level. It positions STSP not only as a vehicle for integrated STEM but also as a framework for bridging STEM and humanities disciplines to design ethically grounded, contextually relevant learning experiences.

Theoretical and Conceptual Framework

This study is underpinned by two interrelated theoretical foundations: Humanizing Pedagogy theory (Bartolomé, 1994; Freire, 2017) and the Scientist-Teacher-Student Partnership (STSP) model (Saat et al., 2021, 2023). Together, these frameworks guide the formulation of the interview protocol, the coding of disciplinary lenses, and the interpretation of students' insights.

Humanizing pedagogy asserts that learners must be positioned as active agents who co-construct knowledge through dialogue, inquiry, and connection to lived realities (Ita Olszewska et al., 2023; Jorgensen, 2022). This informed our emphasis on exploring students' experiences of agency, inquiry, cultural relevance, and ethical meaning-making in STEM lessons. It also guided our analytical attention to indicators of "banking model" practices such as passive note-taking, rigid experiments, and teacher-centred delivery, which students repeatedly described. In this study, the STSP community of practice is expanded to include the humanities field, providing a broader perspective in STEM lessons. The STSP model provides the structural lens for understanding how collaboration among scientists, science teachers, humanities teachers, and students can facilitate interdisciplinary and human-centred STEM learning. STSP moves beyond traditional outreach models by emphasising reciprocal expertise, authentic inquiry, and disciplinary boundary-crossing. This model guided both the design and interpretation of our data by foregrounding the potential for integrating STEM and humanities perspectives, especially ethical, socio-cultural, and contextual dimensions, into classroom practice.

A synthesis of related frameworks further strengthens the conceptual grounding of this study. Humanizing STEM shares conceptual overlap with ethical STEM, which highlights moral reasoning, responsibility, and values in scientific practice (Vedrenne-Gutiérrez et al., 2024), and with the Socio-scientific Issues (SSI) approach, which integrates science learning with real-world dilemmas (Alcaraz-Dominguez & Barajas, 2021; Falah et al., 2024). However, unlike Ethical STEM and SSI, which typically foreground moral or societal issues within science alone, Humanizing STEM explicitly integrates disciplinary perspectives from the humanities (e.g., ethics, social, and cultural). Thus, Humanizing STEM extends beyond issue-based reasoning to reframe STEM learning as culturally situated, ethically grounded, and dialogically co-constructed. Positioning STSP within this landscape shows how it can operationalise humanizing pedagogy by creating structured partnerships that unite epistemic (STEM) and humanistic (humanities) forms of knowledge. Guided by this framework, the study analyses how students perceive current STEM lessons through both STEM-based (inquiry, problem-solving, experimentation) and humanities-based (ethics, culture, social responsibility, community relevance) lenses. This theoretical anchoring informed the interview protocol, the dual-lens coding approach, and the interpretation of students' experiences as indicators of dehumanized or humanized STEM learning.

The integration of STEM and humanities perspectives is operationalised through an interdisciplinary community of practice that brings together scientists, science teachers, humanities scientists, and humanities teachers (refer to Figure 1). STEM contributes epistemic elements such as scientific inquiry, experimentation, and domain knowledge, whereas the humanities contribute ethical reasoning, socio-cultural perspectives, patriotism, and cultural relevance. Rather than treating these domains as separate, the model positions them as co-dependent lenses for understanding learning. This conceptual integration guided the construction of the interview protocol, the coding framework, and the interpretation of themes.
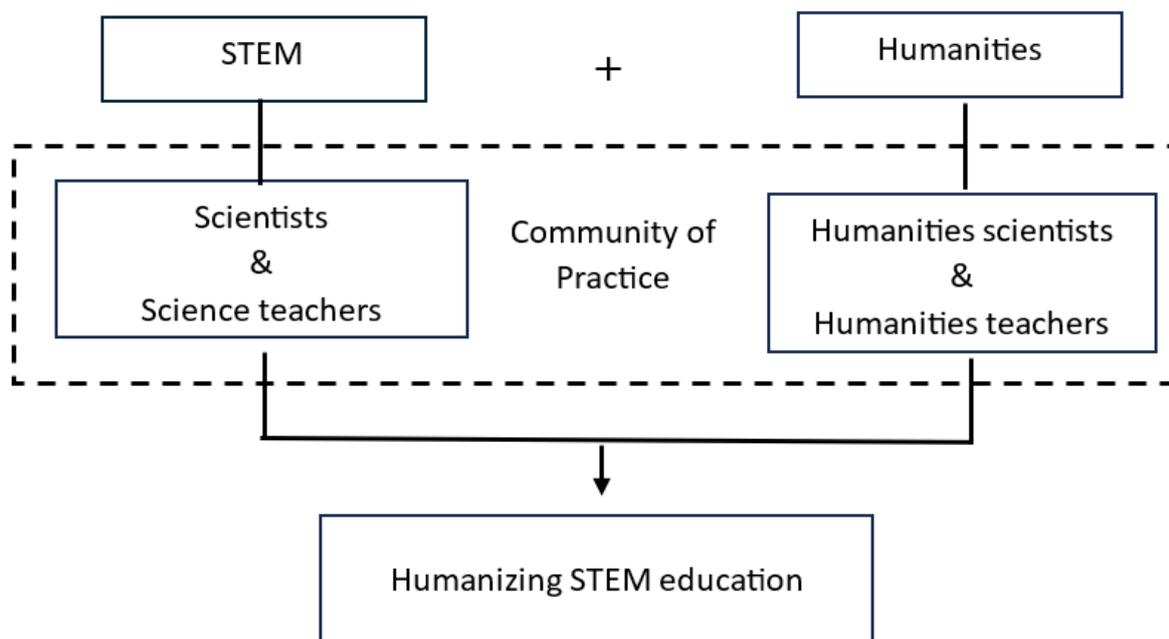
Figure 1. *The Conceptual Framework of Humanizing STEM Through the STSP Approach for Secondary Science Learning*

RESEARCH OBJECTIVE AND RESEARCH QUESTION

Against this backdrop, this study seeks to explore students' insights into their STEM learning experiences, focusing on their perceived needs for humanizing STEM through STSP. Specifically, it aims to identify gaps in current instructional practices, challenges that lead to disengagement, and students' demands for more relevant, ethical, and collaborative learning opportunities. By foregrounding student voices, the study aspires to contribute to the growing body of knowledge on humanizing STEM education while offering practical implications for curriculum design, teacher professional development, and scientist-school collaborations. Therefore, since this study is part of a larger study that focuses on analysing needs from students' perspectives on STEM lessons before humanised STEM through the STSP approach, this study aims to explore secondary school students' insights into the current STEM instructional practices as a needs analysis for designing humanized STEM lessons through STSP. Specifically, it addresses the following research question: What are the perceptions of secondary school students regarding current STEM instructional practices as a basis for humanizing STEM through STSP?

METHODOLOGY

The researchers employed a basic interpretive qualitative research design to explore students' perspectives on current STEM learning, particularly on teachers' instructional approaches. The qualitative research approach was chosen as it is pertinent for collecting rich information to address the research question. A qualitative study seeks to understand how individuals construct meaning, interpret their experiences, and engage with their surroundings (Merriam, 2009). This approach emphasizes the importance of context, existence, experience, perspective, meaning, and subjectivity, allowing for a unique exploration of the complexities inherent in social phenomena (Lim, 2025). Consequently, investigating students' responses to contemporary STEM instruction and their need for meaningful educational practices is regarded as the most effective method. These phenomena can only be examined through qualitative inquiry (Merriam, 2009). Lim (2025) emphasises that this approach provides rich, nuanced insights into complex issues and thoroughly investigates specific contexts, experiences, perceptions, and interactions. This leads to a comprehensive understanding that informs tailored

interventions. Furthermore, this method recognises participant voices' significance, highlighting the role of students as active learners involved in the STSP.

Moreover, the researchers employed the purposive sampling technique (Creswell & Creswell, 2022; Creswell & Poth, 2018) in selecting the participants. Five (5) secondary students (three female, two male), who were 16-year-old students enrolled in an upper-secondary STEM stream in a government secondary school, have been chosen to participate in an in-depth interview in this study. The criterion for selecting participants is that they are 16 years old and from the STEM stream class, ensuring they have experience in STEM lessons. These criteria are crucial in ensuring that they are "knowledgeable informants" (Lincoln & Guba, 1985), which enables researchers to gather as much data as possible for this study. The data were collected through one-to-one semi-structured interviews that utilized an interview protocol reviewed by peer experts to ensure procedural consistency while allowing flexibility for emergent ideas (Merriam, 2009; Lim, 2025), thereby exploring proposed issues and questions.

The semi-structured interview affords the interviewer the flexibility to probe deeper into responses (Merriam, 2009) or follow emerging themes, maintaining a balance between consistency and adaptability (Lim, 2025). Ethical approval for this study was obtained from the University of Malaya Research Ethics Committee (UM.TNC2/UMREC_3853). Permission to collect data in the school was granted by the Ministry of Education Malaysia (KPM.600-3/2/3-eras(21142) through the Education Research Application System (eRAS). Additionally, authorization was secured from the school administration. Written informed consent and assent were obtained from all participants and their guardians. Participants willingly agreed to partake in the research and were assured of confidentiality and privacy. They were required to complete an informed consent form, which signified their willingness to participate and their availability for interview sessions (Saat et al., 2021). All interviews were scheduled according to participants' availability and were conducted over two weeks. Each session was audio-recorded with consent and later transcribed verbatim to ensure data accuracy. The researchers employed thematic analysis, as suggested by Braun & Clarke (2006), to analyse the data. The six-stage process for identifying patterns or themes within qualitative data was followed, starting with familiarization, generating initial codes, searching for themes, reviewing themes, defining and naming themes, and writing up the report. The process of data collection and analysis was conducted iteratively until saturation was achieved (Hennink & Kaiser, 2022; Patton, 2015). Some of the codes, categories, and one theme that emerge are illustrated in Table 1. These categories collectively shape the overarching theme that current STEM lessons are often experienced as decontextualised and dehumanised.

Table 1. *The Examples of Code, Category, And Theme Emerged from The Data Analysis*

Theme	Category	Code
Issues in STEM learning	Limited inquiry and practical engagement	• Copying from slides • Fixed experiment steps • Lack of chance to ask questions • Only confirming the teacher's answers
	Oversight of ethics, social, and cultural perspectives	• Lack of ethics discussion in science • Values only in Moral/Islamic Education • Lack of link to community issues
	Fragmented & Siloed Curriculum	• Subjects taught in isolation • No cross-disciplinary explanations • Multiple subjects teaching the same topic separately • Lack of holistic or integrated lessons • Curriculum feels disjointed

In this study, STEM and humanities are combined methodologically through the use of an interview protocol, coding framework, and theme interpretation. The interview protocol was intentionally designed to capture student experiences from both STEM and humanities dimensions. Questions explored

students' engagement with scientific inquiry, experimentation, and problem-solving (STEM), as well as their exposure to ethics, social issues, culture, history, and community-based topics, which are included in the humanities domain. This ensured that students' accounts reflected multiple disciplinary perspectives.

During the initial coding phase, the researchers employed a dual-lens analytical approach. Codes such as "fixed experiment steps, lack of chance to ask questions, only confirming the teacher's answers" were associated with STEM instructional issues. Concurrently, codes such as "lack of ethics discussion in science, values only in Moral or Islamic Education, lack of link to community issues, and culture not included" were associated with humanities-based perspectives. The final themes emerged not by analysing STEM and humanities codes separately, but by synthesizing them to understand the broader phenomenon of dehumanized or humanized STEM learning. For example, the category "fragmented and siloed curriculum" was developed by integrating STEM codes (subject isolation, redundancy, and limited transfer of knowledge) with humanities codes (lack of ethical-cultural integration and absence of socio-historical perspectives). This combined approach reflects how STEM and humanities were methodologically interwoven throughout the analysis.

To uphold credibility and trustworthiness in data analysis, the researchers employed investigator triangulation to enhance analytical rigor (Ismail et al., 2024; Moon et al., 2019). Multiple researchers independently coded and reviewed the data, followed by systematic comparison and discussion of interpretations to minimize individual bias and strengthen the credibility of the emergent themes (Creswell & Poth, 2018). Two scholars in the field of science education have reviewed the interview protocol and the established themes during the data analysis process. A triangulation strategy was used to strengthen the credibility of the analysis. Triangulation helps mitigate bias by employing multiple approaches to investigate a problem, thereby enhancing the study's internal validity (Natow, 2019; Schlunegger et al., 2024).

FINDINGS AND DISCUSSION

Based on the data analysis, the researchers gained numerous insights per the participants' perspectives on STEM lessons before the need analysis of humanizing STEM through STSP. Based on the analysis conducted, three themes emerged, which are (1) issues in STEM learning, (2) instructional strategy in STEM lessons, and (3) elements needed in humanizing STEM lessons. However, for this paper, the researchers will only discuss the first theme of the study, which is issues in STEM learning. In reporting the findings, we first describe students' accounts of current STEM lessons and then interpret these accounts through the lens of humanizing STEM and the STSP framework. The following subsequent subheadings describe the themes more extensively:

Issues in STEM learning
The participants' accounts reveal several systemic and pedagogical issues that make STEM learning detached, fragmented, and unappealing. These issues reduce students' engagement and restrict the transformative potential of STEM education. Based on the participants' feedback, three categories have been classified under this theme, namely: (1) limited inquiry and practical engagement, (2) oversight of values and ethics in STEM lessons, and (3) fragmented and siloed curriculum.

Limited Inquiry and Practical Engagement
Based on the findings, several participants emphasized that opportunities for inquiry-based learning and hands-on practical engagement in STEM lessons were scarce, heavily structured, or superficial. Laboratory sessions, when conducted, often follow rigid step-by-step procedures with little room for students to design, question, or test their own hypotheses. Project-based learning was also limited, leaving students feeling disengaged from authentic scientific practices. Below shows some excerpts of participants' concerns:

> …most of the time, the teacher explains everything using PowerPoint presentations, and we simply copy from the slides. There is little to no opportunity for us to share our own ideas; we just follow

what the teacher says. During experiments, we are given a specific procedure to follow, and if we do not adhere to it exactly, we risk getting scolded. We only do experiments to prove what the teacher already taught. It's like just confirming the answer, not really exploring (P1. Ln.11-16).

…in science class, we typically just listen to the teacher's instructions while conducting the experiment. There isn't much opportunity for us to ask questions freely. We don't get to ask our own questions or design experiments. Everything is fixed, so we just follow instructions (P2. Ln.13-16).

In experiments, we just follow the steps exactly as written. We don't really get to test our own ideas. I want to try different methods in experiments, but the teacher says we must stick to the manual because of time constraints and focus on the exams (P3. Ln.18-20).

…in my opinion, studying science often feels like simply memorizing information and trying to comprehend what the teacher is explaining, rather than engaging in exploration or discovery. Most experiments are already given to us with answers. We just follow, and it doesn't feel exciting. I want to try real projects, like solving problems in our community, but in class it's just theory (P4. Ln.15-19).

STEM education is meant to be practical, yet we often miss out on hands-on activities that relate to real-life situations. In some cases, if we do not conduct the experiments or do not achieve the expected results, the teacher simply asks us to use pre-existing data for our lab reports or to construct graphs (P5. Ln.18-22).

Based on the findings, it was observed that teachers often do not provide students with opportunities to design and explore ideas or solutions for assigned problems and tasks. This tendency is primarily due to time constraints and a lack of confidence in students' ability to explore independently. Consequently, practical work is predominantly regarded as a verification exercise rather than an inquiry process, which significantly limits opportunities for critical thinking, problem-solving, and creativity. Instruction is frequently delivered through lecture-style teaching, PowerPoint presentations, and rote note-taking, leaving little room for inquiry, interaction, questioning, or collaborative exploration. This approach positions the teacher as the sole authority on knowledge, while students assume passive roles as mere recipients of information.

Furthermore, students highlighted that science lessons are heavily structured around syllabus requirements and examinations. While teachers are dedicated to content delivery, their instructional practices tend to be traditional, providing limited opportunities for inquiry, collaboration, or ethical reflection. This has resulted in a learning environment that feels disconnected from the realities of the students' experiences.

This highlights students' frustration with rote verification rather than authentic inquiry. Such a limited agency aligns with Freire's critique of the "banking model of education" (Freire, 2017; Ita Olszewska et al., 2023) and echoes recent studies showing that STEM classrooms remain dominated by lecture-style instruction (Lin et al., 2023; Olitsky, 2017). The current teacher-centred instructional approach reduces opportunities for problem-solving, critical thinking, and real-world application. It reinforces a compliance-based classroom culture rather than cultivating curiosity and innovation. This finding is aligned with earlier studies reporting that Malaysian STEM classrooms are facing. Traditional, lecture-based instruction approaches are ineffective in engaging students in these dynamic and hands-on subjects (López-Belmonte et al., 2022; Sims & Jerrim, 2022). There is a lack of time to nurture students' critical thinking through conducting experiments or project-based learning due to the extensive syllabi (Riduan & Othman, 2024). Pressure to cover extensive syllabi within limited timeframes leads to rushed teaching. Teacher-centred instruction, while ensuring coverage of content, fails to embody the principles of humanizing pedagogy (Bartolomé, 1994). Several studies highlight the importance of inquiry-based learning in science education (Kersting et al., 2023; Strat et al., 2024). STSP has the potential to transform this dynamic by positioning not only scientists, but also humanities scientists and teachers as

co-facilitators of inquiry, where students can critically engage with socio-scientific issues, voice perspectives, and participate in co-constructing knowledge.

From a humanizing STEM perspective, students' descriptions of highly structured, verification-oriented practical work reflect what Freire (2017) terms a "banking model" of education, where learners are positioned as passive recipients rather than co-constructors of knowledge. This stands in tension with humanizing pedagogy, which emphasises dialogic inquiry, agency, and problem-posing around meaningful issues. Within the STSP framework, these findings underscore the importance of scientists and humanities scientists collaborating to design inquiry-rich experiences with teachers and students that extend beyond confirming textbook answers to exploring authentic, community-relevant problems.

Oversight of Ethics, Social, and Cultural in STEM Lessons

Participants noted that discussions about ethical dilemmas, social, and cultural perspectives in science are rare. Participants highlighted that science and STEM lessons were often framed as "technical-only," lacked values, and had little to no emphasis on ethics, cultural context, or social responsibility. While lessons focused on equations, experiments, and factual content, they rarely explored *why* science matters for society, *how* scientific advancements affect communities, or *what* ethical responsibilities scientists and citizens have in applying scientific knowledge. Several participants felt that the human dimension of science was largely absent. They described lessons as disconnected from moral and cultural realities, particularly issues relevant to their communities, such as environmental degradation, plastic pollution, or sustainability. The following excerpts indicate their responses:

> In science class, we learn about climate change and the scientific concepts that lead to global warming. However, we only scratch the surface when discussing ways to address this issue. We are often not aware of our actual roles in mitigating global warming. The ways to overcome are usually that the teachers ask us to read on our own (P1. Ln.20-23).

> The teacher does not ask us about what we think is right or wrong regarding scientific issues. The teacher did not mention ethical reasoning. We just have the content provided. Teachers rarely discuss values and seldom mention culture in science (P2. Ln.22-24).

> I think ethics and values are primarily taught in Moral or Islamic studies, but not in science. For example, when we learn about pollution in science, we cover the same topic in Geography as well. While both subjects discuss pollution, Geography also emphasizes law enforcement and legislation, such as the Environmental Quality Act of 1974. It might be beneficial to combine these subjects for a more comprehensive understanding (P3. Ln.26-31).

> In class, the teacher explains the content but rarely discusses why science matters to our society, how scientific developments affect our communities, or what ethical responsibilities we should have in applying scientific knowledge (P4. Ln.29-31).

The findings show that students recognize a missing moral and cultural dimension in STEM lessons, where science is presented as purely technical. Such concerns highlight how ethics, social, and cultural relevance are side-lined in current classrooms. Prior studies similarly caution that STEM education often portrays science as value-neutral (Ismail et al., 2022; Roehrig et al., 2021; Shahali & Halim, 2024; Tytler et al., 2023), overlooking ethical, social, and cultural dimensions in STEM learning. The neglect of ethics, social, and cultural values in STEM classrooms reflects that STEM and science are presented as objective, value-neutral, and divorced from moral or social dimensions. Nevertheless, social and ethical values are critical to the practice of science (Douglas, 2023; Linville et al., 2023). The students' insight extends existing literature by adding ethical, social, and cultural perspectives to the secondary STEM classroom. These perspectives, which fall under the umbrella of the humanities, are essential for fostering a more comprehensive understanding of the world (Azizi et al., 2023; Cook-Sather et al., 2023; Imad et al., 2023), particularly when addressing socio-scientific issues (SSI) (Macalalag et al., 2024; Ozturk & Roehrig, 2025; Tang et al., 2024; Wahono et al., 2021). By voicing this gap, students extend these

critiques by emphasizing the absence of community-relevant issues, suggesting the urgency of embedding ethics, social, and cultural issues in STEM learning.

Several students lack familiarity with ethics as a discipline, which limits their ability to articulate their perspectives or engage in reasoned discussions surrounding ethical issues in science (Chowdhury, 2016; Kreth et al., 2024). To cultivate an active and informed citizenry, students must develop analytical and critical thinking skills that enable them to apply ethical reasoning in the face of scientific controversies (Chowdhury et al., 2020). Teachers bear the responsibility not only to enhance students' decision-making abilities but also to guide them in thoughtfully considering diverse viewpoints, overcoming biases, and effectively expressing their dissenting opinions (Isma'il et al., 2021). Several studies also emphasize that, alongside technical proficiency, there is a growing recognition of the importance of soft skills such as ethical reasoning, teamwork, and communication within STEM education (Karimi & Pina, 2021; Marzuki et al., 2024; Pavlica et al., 2020; Villán-Vallejo et al., 2022). This highlights the necessity of a humanized approach to science and STEM education (Klopfer & Aikenhead, 2022) that empowers students to engage in ethical reflection and critical thinking, equipping them to navigate complex situations in their daily lives (Azizi et al., 2023; Chowdhury et al., 2020; Cook-Sather et al., 2023; Imad et al., 2023).

These highlight that, in students' experience, ethics, culture, and social responsibility are compartmentalized into subjects such as Moral Education, Islamic Education, or Geography, rather than being integrated into science and STEM lessons. This separation fragments students' moral and scientific reasoning, undermining the humanizing aim of preparing ethically responsible citizens. STSP offers a platform to reconnect these dimensions: scientists can introduce real-world socio-scientific issues, while humanities experts facilitate ethical deliberation and cultural reflection, thereby positioning STEM learning within students' lived moral worlds.

Fragmented and Siloed Curriculum

Participants consistently reported that their learning in STEM is compartmentalized by subject boundaries. STEM is often taught in isolation, with little or no effort to draw explicit connections between it and other disciplines, such as the humanities and social sciences. This compartmentalization makes it difficult for students to appreciate the relevance of STEM in real-world problem-solving, which often requires interdisciplinary integration. Several participants remarked,

> What we learn in biology has nothing to do with what we learn in moral or Islamic education. It feels like separate worlds. The teacher also never told us that it could be connected (P3 Ln. 33-34).

> Emerging issues such as global warming are connected to various subjects, including the subtopic of green technology, which we covered in geography during Form 2. However, green technology is not addressed in lower-form science. My teacher said we will revisit this topic in upper form, particularly in biology or chemistry. This overlap seems a bit redundant, as we are likely to study it again in upper forms, especially in science subjects (P4 Ln. 35-39).

> Sometimes I wonder why certain subtopics, such as domestic waste and the 3Rs (reduce, reuse, recycle), are taught in both science and geography. Why not merge them into one comprehensive lesson? Studying these topics separately doesn't reflect how real-life problems are interconnected. It would be more effective to approach them holistically (P5 Ln. 28-31).

This reflects the current siloed learning experience that limits students' ability to transfer knowledge across domains and see the bigger picture of how STEM interacts with society, culture, and the environment. STEM education is moving towards Interdisciplinary Learning, which encourages curricula that incorporate different STEM fields and beyond, reflecting the interconnected nature of these disciplines in real-world circumstances (Marzuki et al., 2024). Previous studies have shown emerging trends in incorporating the humanities in STEM curricula (Bourdeau, 2021; Faulconer et al., 2020; Pavlica et al., 2020). It is paramount to recognize and understand this relationship in tackling pressing global challenges within the sphere of STEM education (Bunnell et al., 2021; Bunnell et al., 2023; Liao

et al., 2022). Implementing a human-centred approach to STEM as early as the secondary school stage is crucial for instilling ethical and social responsibilities and fostering cultural relevance in students. This approach seeks to establish a deeper connection between students and the world around them, thereby enhancing their understanding of STEM concepts.

Students' frustration with overlapping topics across subjects, without explicit connection, underscores how current curricula inadvertently reinforce disciplinary silos. Humanizing STEM requires that learners see how scientific, ethical, legal, and cultural perspectives intersect in addressing problems such as pollution or climate change. Within an STSP configuration, collaboration between science and humanities teachers and scientists can scaffold interdisciplinary projects (e.g., linking environmental science, environmental law, and local cultural practices) that mirror the complexity of real-world challenges.

To synthesise the themes, the three issues identified by students, limited inquiry opportunities, the absence of ethical and cultural perspectives, and fragmented disciplinary learning, collectively illustrate how current STEM experiences are perceived as decontextualised and dehumanised. Interpreting these issues through the humanizing STEM lens suggests the need for pedagogical models that restore agency, foster meaning-making, and promote ethical awareness in STEM learning. Figure 2 presents a conceptual model illustrating how these issues inform the rationale for humanizing STEM and how the STSP model serves as a vehicle for operationalizing this vision.
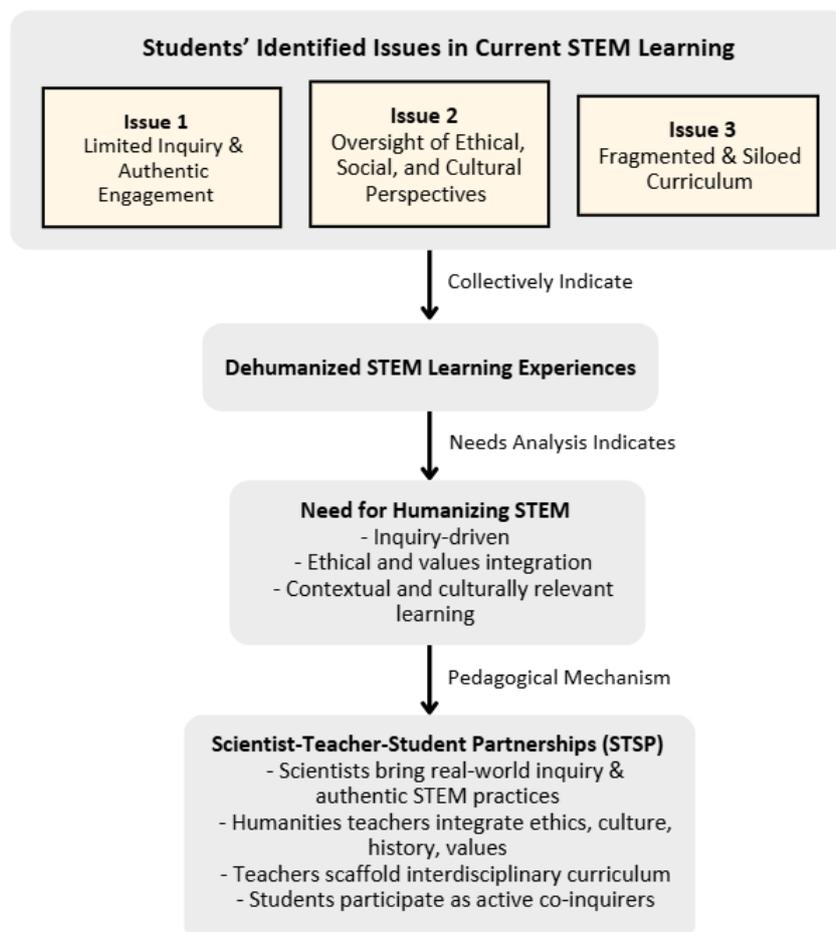

Figure 2. *The Findings Illustrate How These Issues Inform the Rationale for Humanizing STEM And How the STSP Framework Serves as A Vehicle for Operationalizing This Vision*

CONCLUSION

In conclusion, this study highlights how students perceive current STEM lessons as being constrained by teacher-centred practices that offer limited inquiry opportunities and overlook the ethical, social, and cultural dimensions, resulting in fragmented and disengaging learning experiences. Their voices reveal a pressing need to reframe STEM education through approaches that foreground inquiry, interdisciplinarity, and humanistic values. The findings affirm that while technical knowledge remains central, students seek learning that connects science to real-world issues, cultivates ethical reflection, and encourages agency in problem-solving. Positioning the STSP as a vehicle for this transformation, the study underscores its potential to bridge disciplinary divides and foster authentic, humanized learning experiences. By integrating the expertise of scientists and humanities scientists, teachers' pedagogical strategies, and students' lived realities, STSP can help realign STEM education with the broader goal of nurturing critical, responsible, and empathetic citizens. This needs analysis thus provides not only evidence of the gaps in current practices but also direction for future curriculum design and partnerships aimed at advancing humanizing STEM in secondary education.

The findings suggest that humanizing STEM at the secondary level requires redesigning lessons to foreground inquiry, ethical reflection, and interdisciplinary connections. Practically, teachers can co-plan STSP projects with scientists and humanities teachers that centre on local socio-scientific issues (e.g., waste management, climate resilience) and explicitly integrate ethical, legal, and cultural perspectives. At the policy level, the results align with the Malaysian 2027 School Curriculum's emphasis on holistic, value-based education and support the inclusion of structured opportunities for scientist–school partnerships that involve both STEM and humanities disciplines. This study is limited by its small sample of five students from a single school and by its focus solely on students' perspectives before the STEM lessons. The findings should therefore be interpreted as context-bound and exploratory rather than generalisable. Nevertheless, the rich qualitative accounts provide a valuable starting point for designing and evaluating humanizing STEM interventions. Future studies could expand this work by involving a larger and more diverse sample of schools and by incorporating the perspectives of science and humanities teachers as well as scientists engaged in STSP.

ACKNOWLEDGEMENT

REFERENCES

Alcaraz-Dominguez, S., & Barajas, M. (2021). Conceptualization of socioscientific issues in educational practice from a review of research in science education. *International Journal of Information and Education Technology*, *11*(6), 297–302. https://doi.org/10.18178/ijiet.2021.11.6.1526

Azizi, M., Imad, M., Foote, S. M., Caulkins, J., & Wuetherick, B. (2023). Humanizing STEM education: An exploratory study of faculty approaches to course redesign. *Frontiers in Education*, *8*(July), 1–10. https://doi.org/10.3389/feduc.2023.1181157

Bartolomé, L. (1994). Beyond the methods fetish: Toward a humanizing pedagogy. *Harvard Educational Review*, *64*(2), 173–195. https://doi.org/10.17763/haer.64.2.58q5m5744t325730

Bourdeau, D. (2021). Humanistic STEM: From concept to course. *Journal of Humanistic Mathematics*, *11*(1), 33–53. https://doi.org/10.5642/jhummath.202101.04

Bunnell, Sarah L., Jaswal, S. S., & Lyster, M. (2023). *Being human in STEM: Partnering with students to shape inclusive practices and communities*. Stylus Publishing. https://doi.org/10.4324/9781003443216

Bunnell, S., Lyster, M., Greenland, K., Mayer, G., Gardner, K., Leise, T., Kristensen, T., Ryan, E. D., Ampiah-Bonney, R., & Jaswal, S. S. (2021). From protest to progress through partnership with students: Being human in STEM (HSTEM). *International Journal for Students as Partners*, *5*(1), 26–56. https://doi.org/10.15173/ijsap.v5i1.4243

Chowdhury, M. (2016). Emphasizing morals, values, ethics, and character education in science education and science teaching. *Malaysian Online Journal of Educational Sciences*, *4*(2), 1–16.

Chowdhury, T. B. M., Holbrook, J., & Rannikmäe, M. (2020). Addressing sustainable development: Promoting active informed citizenry through trans-contextual science education. *Sustainability (Switzerland)*, *12*(8). https://doi.org/10.3390/SU12083259

Commissioner of Law Revision, Malaysia. (2012). *Education Act 1996 (Act 550)*. https://tcclaw.com.my/wp-content/uploads/2025/07/Education-Act-1996.pdf

Cook-Sather, A., Salmeron, D., & Smith, T. (2023). Humanizing STEM education through student-faculty pedagogical partnerships. *Frontiers in Education*, *8*(June), 1–16. https://doi.org/10.3389/feduc.2023.1153087

Creswell, J. W ., & Poth, C. N. (2018). *Qualitative inquiry and research design: Choosing among five approaches* (4th ed.). SAGE Publications. https://us.sagepub.com/en-us/nam/qualitative-inquiry-and-research-design/book246896

Creswell, J. W., & Creswell, J. D. (2022). *Research design: Qualitative, quantitative, and mixed methods approaches*. SAGE Publication. https://libro.eb20.net/Reader/rdr.aspx?b=210602683

Douglas, H. (2023). The importance of values for science. *Interdisciplinary Science Reviews*, *48*(2), 251–263. https://doi.org/10.1080/03080188.2023.2191559

Eccles, J. S., & Wigfield, A. (2020). From expectancy-value theory to situated expectancy-value theory: A developmental, social cognitive, and sociocultural perspective on motivation. *Contemporary Educational Psychology*, *61*(May), 101859. https://doi.org/10.1016/j.cedpsych.2020.101859

Edwards, L., & Ritchie, B. (2022). Challenging and confronting: The role of humanities in fostering critical thinking, cultural competency and an evolution of worldview in enabling education. *Student Success*, *12*(3), 1–11. https://doi.org/10.5204/ssj.2011

Fadzil, H. M., Saat, R. M., Awang, K., & Adli, D. S. H. (2019). Students' perception of learning stem-related subjects through scientist-teacher-student partnership (STSP). *Journal of Baltic Science Education*, *18*(4), 537–548. https://doi.org/10.33225/jbse/19.18.537

Falah, M. M., Hartono, Nugroho, S. E., & Ridlo, S. (2024). Socio-scientific issues (SSI) research trends: A systematic literature review of publications 2011 – 2022. *Journal of Turkish Science Education*, *21*(1), 61–81. https://doi.org/10.36681/tused.2024.004

Faulconer, E. K., Wood, B., & Griffith, J. C. (2020). Infusing humanities in STEM education: Student opinions of disciplinary connections in an introductory chemistry course. *Journal of Science Education and Technology*, *29*(3), 340–345. https://doi.org/10.1007/s10956-020-09819-7

Freire, P. (2017). (2017). *Pedagogy of the oppressed*. Penguin Classics. https://www.penguin.co.uk/books/22583/pedagogy-of-the-oppressed-by-freire paulo/9780241301111

Hendrickson, K. A., & Blackmon, A. T. (2025). Humanizing STEM Education, valuing cultures of care through conscious values-based leadership. *Innovative Higher Education*, *50*(3), 1041–1061. https://doi.org/10.1007/s10755-024-09770-0

Hennink, M., & Kaiser, B. N. (2022). Sample sizes for saturation in qualitative research: A systematic review of empirical tests. *Social Science and Medicine*, *292*, 114523. https://doi.org/10.1016/j.socscimed.2021.114523

Imad, M. (2020). What would Socrates think? *Change: The magazine of higher learning*, *52*(6), 17–21. https://doi.org/10.1080/00091383.2020.1839316

Imad, M., Reder, M., Rose, M., & Jaswal, S. S. (2023). Recasting the agreements to re-humanize STEM education. *Frontiers in Education*, *8*(October), 1–21. https://doi.org/10.3389/feduc.2023.1193477

Isma'il, A., Suleiman, B., & Aliu, A. (2021). Ethics and strategies for its integration into Science, Technology, Engineering and Mathematics (STEM) classrooms at secondary school level. In A. S. Ifamuyiwa (Ed.), *Ethic and STEM Education* (Issue August, pp. 26–34). Science Teachers Association of Nigeria.

Ismail, M. H., Fadzil, H. M., Saat, R. M., & Salleh, M. F. M. (2022). A needs analysis study for the preparation of integrated STEM instructional practices through Scientist-Teacher-Student Partnership (STSP). *ASM Science Journal*, *17*. https://doi.org/10.32802/ASMSCJ.2022.1112

Ismail, M. H., Fadzil, H. M., Salleh, M. F. M., Saat, R. M., Kurniawan, C., & Hariyono, E. (2024). Science teachers' instructional practices: A need analysis for preparing integrated STEM practices through

scientist-teacher-student partnership. *Asian Journal of University Education*, *20*(3), 630–644. https://doi.org/10.24191/ajue.v20i3.27858

Ismail, M. H., Fadzil, H., Mohd Saat, R., & Mat Salleh, M. F. (2022). Students' view on STEM lessons: An analysis of needs to design integrated STEM instructional practices through scientist-teacher-students partnership (STSP). *Malaysian Online Journal of Educational Sciences*, *10*(April), 1–12.

Ita Olszewska, A., Bondy, E., Hagler, N., & Jinna Kim, H. (2023). A humanizing pedagogy of engagement: Beliefs and practices of award-winning instructors at a U.S. university. *Teaching in Higher Education*, *28*(7), 1671–1687. https://doi.org/10.1080/13562517.2021.1920575

Jorgensen, M. (2022, May 15). *Humanizing pedagogy: Changing the field of education* (Cal State ScholarWorks). California State University.

Karimi, H., & Pina, A. (2021). Strategically addressing the soft skills gap among STEM undergraduates. *Journal of Research in STEM Education*, *7*(1), 21–46. https://doi.org/10.51355/jstem.2021.99

Kersting, M., Karlsen, S., Ødegaard, M., Olufsen, M., Kjærnsli, M., & Suhr Lunde, M. L. (2023). Studying the quality of inquiry-based teaching in science classrooms. A systematic video study of inquiry-based science teaching in primary and lower-secondary schools. *International Journal of Science Education*, *45*(17), 1463–1484. https://doi.org/10.1080/09500693.2023.2213386

Klopfer, L. E., & Aikenhead, G. S. (2022). Humanistic science education: The history of science and other relevant contexts. *Science Education*, *106*(3), 490–504. https://doi.org/10.1002/sce.21700

Kreth, Q., Schiff, D. S., Lee, J., Borenstein, J., & Zegura, E. (2024). *Social responsibility and ethics in STEM Education: The state of the field* (pp. 19–33). https://doi.org/10.1007/978-3-031-51560-6_2

Liao, S.-M., Bunnell, S., & Jaswal, S. (2022). A call for being human in undergraduate statistics. *IASE / ICOTS 11 Proceedings*, *11*, 1–6. https://doi.org/10.52041/iase.icots11.t1f2

Lim, W. M. (2025). What is qualitative research? An overview and guidelines. *Australasian Marketing Journal*, *33*(2), 199–229. https://doi.org/10.1177/14413582241264619

Lin, X., Luan, L., & Dai, Y. (2023). Exploring Chinese STEM college students' expectations of effective online courses. *International Journal of Chinese Education*, *12*(2), 1–20. https://doi.org/10.1177/2212585X231188977

Lincoln, Y. S., & Guba, E. G. (1985). *Naturalistic inquiry*. SAGE Publications.

Linville, C. L., Cairns, A. C., Garcia, T., Bridges, B., Herington, J., Laverty, J. T., & Tanona, S. (2023). How do scientists perceive the relationship between ethics and science? A pilot study of scientists' appeals to values. *Science and Engineering Ethics*, *29*(3), 1–23. https://doi.org/10.1007/s11948-023-00429-1

López-Belmonte, J., Segura-Robles, A., Moreno-Guerrero, A. J., & Parra-González, M. E. (2022). Comparative analysis between a STEM-based learning process and traditional teaching. *South African Journal of Education*, *42*(December), 1–10. https://doi.org/10.15700/saje.v42ns1a2057

Macalalag, A. Z., Kaufmann, A., Van Meter, B., Ricketts, A., Liao, E., & Ialacci, G. (2024). Socioscientific issues: Promoting science teachers' pedagogy on social justice. *Disciplinary and Interdisciplinary Science Education Research*, *6*(1). https://doi.org/10.1186/s43031-024-00118-4

Marzuki, O. F., Lih, E. T. Y., Zainol @ Abdullah, W. N. Z., Khairuddin, N., Inai, N. H., Md Saad, J. B., & Abdul Aziz, M. H. (2024). Innovating education: A comprehensive review of STEM education approaches. *International Journal of Academic Research in Progressive Education and Development*, *13*(1), 614–631. https://doi.org/10.6007/ijarped/v13-i1/20490

Masson, A. L., Klop, T., & Osseweijer, P. (2016). An analysis of the impact of student–scientist interaction in a technology design activity, using the expectancy-value model of achievement related choice. *International Journal of Technology and Design Education*, *26*(1), 81–104. https://doi.org/10.1007/s10798-014-9296-6

Merriam, S. B. (2009). Qualitative research a guide to design and implementation. In *Higher and adult education series* (2nd ed.). Jossey-Bass.

Ministry of Education. (2025). Kurikulum persekolahan 2027 terkini. In *KPM* (pp. 1–14). https://www.moe.gov.my/kurikulum-persekolahan-2027

Ministry of Education. (2017). *History: Curriculum and assessment standard document (DSKP) Form 3* (1st ed.).

Moon, M. D., Rn, M. S. N., & Faen, C. C. E. N. (2019). Triangulation: A method to increase validity, reliability, and legitimation in clinical research. *Journal of Emergency Nursing*, *45*(1), 103–105. https://doi.org/10.1016/j.jen.2018.11.004

Natow, R. S. (2019). The use of triangulation in qualitative studies employing elite interviews. *Qualitative Research, 20*(2), 160–173. https://doi.org/10.1177/1468794119830077

Olitsky, S. (2017). Crossing the boundaries: Solidarity, identity, and mutual learning in a K-20 partnership. *Science Education, 101*(3), 399–425. https://doi.org/10.1002/sce.21272

Ozturk, N., & Roehrig, G. H. (2025). Effects of an integrated STEM Unit designed around socioscientific issues on middle school students' socioscientific reasoning. *International Journal of Science and Mathematics Education, 23*(5), 1493–1518. https://doi.org/10.1007/s10763-024-10517-8

Patton, M. Q. (2015). *Qualitative research & evaluation methods*. *SAGE* Publications. https://doi.org/10.1590/s1415-65552003000200018

Pavlica, M., Babic, T., & Cuculic, P. (2020). Effective decision making: The added value of including humanities in STEM studies. In *2020 43rd International Convention on Information, Communication and Electronic Technology (MIPRO)* (pp. 641–647). IEEE. https://doi.org/10.23919/MIPRO48935.2020.9245347

Primadianningsih, C., Sumarni, W., & Sudarmin, S. (2023). Systematic literature review: Analysis of ethno-STEM and student's chemistry literacy profile in 21st century. *Jurnal Penelitian Pendidikan IPA, 9*(2), 650–659. https://doi.org/10.29303/jppipa.v9i2.2559

Riduan, M. A., & Othman, Z. S. (2024). Examining challenges and strategies in implementing STEM education in Malaysian secondary schools: perspectives of teachers and students. *Jurnal Intelek, 19*(2), 96–106. https://doi.org/10.24191/ji.v19i2.26514

Roehrig, G. H., Dare, E. A., Ellis, J. A., & Ring-Whalen, E. (2021). Beyond the basics: A detailed conceptual framework of integrated STEM. *Disciplinary and Interdisciplinary Science Education Research, 3*(1). https://doi.org/10.1186/s43031-021-00041-y

Saat, R. M., Fadzil, H. M., Adli, D. S. H., & Awang, K. (2021). STEM teachers' professional development through scientist-teacher-students partnership (STSP). *Jurnal Pendidikan IPA Indonesia, 10*(3), 357–367. https://doi.org/10.15294/JPII.V10I3.27845

Saat, R. M., Piaw, C. Y., & Fadzil, H. M. (2023). Creating a grounded model of performance quality of scientist-teacher-student partnership (STSP) for STEM education. *International Journal of Science and Mathematics Education, 21*(1), 325–345. https://doi.org/10.1007/s10763-021-10236-4

Sarkingobir, Y., & Bello, A. (2024). Enhancing critical thinking through ethnoscience-integrated problem-based learning: A comparative study in secondary education. *International Journal of Ethnoscience and Technology in Education, 1*(1), 1. https://doi.org/10.33394/ijete.v1i1.10878

Schlunegger, M. C., Zumstein-Shaha, M., & Palm, R. (2024). Methodologic and data-analysis triangulation in case studies: A scoping review. *Research in Nursing & Health.* Advance online publication. https://doi.org/10.1177/01939459241263011

Shahali, E. H. M., & Halim, L. (2024). The influence of science teachers' beliefs, attitudes, self-efficacy and school context on integrated STEM teaching practices. *International Journal of Science and Mathematics Education, 22*(4), 787–807. https://doi.org/10.1007/s10763-023-10403-9

Sims, S., & Jerrim, J. (2022). *Traditional and progressive orientations to teaching: New empirical evidence on an old debate* (CEPEO Working Paper No. 22-08, pp. 2–51). UCL Centre for Education Policy & Equalising Opportunities. https://econpapers.repec.org/RePEc:ucl:cepeow:22-08

Strat, T. T. S., Henriksen, E. K., & Jegstad, K. M. (2024). Inquiry-based science education in science teacher education: A systematic review. *Studies in Science Education, 60*(2), 191–249. https://doi.org/10.1080/03057267.2023.2207148

Sumarni, W., Faizah, Z., Subali, B., Wiyanto, W., & Ellianawati. (2020). The urgency of religious and cultural science in stem education: A meta data analysis. *International Journal of Evaluation and Research in Education, 9*(4), 1045–1054. https://doi.org/10.11591/ijere.v9i4.20462

Sumarni, W., Wahyuni, S., & Sulhadi. (2023). The effect of application of ethno-STEM integrated project-based learning on increasing students' scientific literacy. *AIP Conference Proceedings, 2614*(September). https://doi.org/10.1063/5.0126208

Tang, K. Y., Lin, T. C., & Hsu, Y. S. (2024). Status and trends of socioscientific issues in educational literature: insights and extensions from a co-word analysis. *International Journal of Science Education, 46*(11), 1073–1097. https://doi.org/10.1080/09500693.2023.2272603

Tytler, R., Anderson, J., & Williams, G. (2023). Exploring a framework for integrated STEM: Challenges and benefits for promoting engagement in learning mathematics. *ZDM - Mathematics Education, 55*(7), 1299–1313. https://doi.org/10.1007/s11858-023-01519-x

UNESCO. (2022). Advocacy, practice and awareness handbook for teachers: Global citizenship education. Asia-Pacific Centre of Education for International Understanding (APCEIU). https://unesdoc.unesco.org/ark:/48223/pf0000384105

Vedrenne-Gutiérrez, F., López-Suero, C. del C., De Hoyos-Bermea, A., Mora-Flores, L. P., Monroy-Fraustro, D., Orozco-Castillo, M. F., Martínez-Velasco, J. F., & Altamirano-Bustamante, M. M. (2024). The axiological foundations of innovation in STEM education – A systematic review and ethical meta-analysis. *Heliyon*, *10*(12). https://doi.org/10.1016/j.heliyon.2024.e32381

Villán-Vallejo, A., Zitouni, A., García-Llamas, P., Fernández-Raga, M., Suárez-Corona, A., & Baelo, R. (2022). Soft skills and STEM Education: Vision of the European university EURECA-PRO. *BHM Berg-Und Hüttenmännische Monatshefte*, *167*(10), 485–488. https://doi.org/10.1007/s00501-022-01275-7

Wahono, B., Chang, C.-Y., & Khuyen, N. T. T. (2021). Teaching socio-scientific issues through integrated STEM education: An effective practical averment from Indonesian science lessons. *International Journal of Science Education*, *43*(16), 2663–2683. https://doi.org/10.1080/09500693.2021.1983226

Yahya, N., Fadzil, H. M., Nor, M., & Abdullah, S. (2025). Mapping the landscape of scientist-school partnerships in STEM education: A bibliometric analysis. *International Journal of Modern Education (IJMOE)*, *7*(26), 108–125. https://doi.org/10.35631/IJMOE.726008

Yao, C., Follmer Greenhoot, A., Mack, K., Myrick, C., Poolaw, J., Powell, L., & Yarger, L. (2023). Humanizing STEM education: An ecological systems framework for educating the whole student. *Frontiers in Education*, *8*(October), 1–9. https://doi.org/10.3389/feduc.2023.1175871

Zhan, Z., & Niu, S. (2023). Subject integration and theme evolution of STEM education in K-12 and higher education research. *Humanities and Social Sciences Communications*, *10*(1), 1–13. https://doi.org/10.1057/s41599-023-02303-8