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Zeyu Han, Chen Chen, Thomas K. F. Chiu, Kejian Qiu, Lili Yang, Zhaoji Wang & Kennedy Kam Ho Chan

As an end or as a means to an end: Positioning empathy in STEM education

Abstract

Background

The public often perceives STEM disciplines as objective and neutral from human and societal factors. However, recent movements in STEM education have increasingly challenged this value-free assumption, advocating for the integration of empathy into STEM education reform. How STEM education leaders view the role of empathy profoundly influences STEM education policy and curriculum design, yet our knowledge of this remains very limited globally. We interviewed 26 STEM education leaders in Hong Kong—comprising university faculty, secondary and primary school science/STEM teachers, and out-of-school STEM education providers. We develop and employ a novel analytical framework of two-fold orientations in STEM education (utilitarian-oriented and humanist-oriented) to interpret our empirical data.

Results

Thematic analysis revealed that empathy serves dual roles in STEM education: as a "tool" (utilitarian orientation) and as an "aim" (humanist orientation), with leaders referencing the latter twice more frequently. As a tool, participants identified empathy's utility for (1) capturing student attention and (2) facilitating problem-solving in design activities, with notable consensus across all panel groups regarding its procedural value. As an aim, participants positioned empathy as (1) a fundamental educational value embodied in the creed for education and value-based pedagogy, (2) an essential component in defining STEM's disciplinary boundaries, and (3) an ultimate goal focused on social service and transformative outcomes. These views vary according to their professional roles—school-based educators strongly emphasized empathy's role as an educational value and goal, while university faculty and out-of-school STEM

education providers expressed concerns about the potential dilution of disciplinary boundaries.

Conclusions

While leaders demonstrated consensus regarding empathy's instrumental role in STEM education, notable disagreements emerged concerning its incorporation as an educational aim, particularly regarding disciplinary boundaries. The pattern of responses suggests that leaders' professional contexts strongly influence their view of empathy's role in STEM education. Our two-fold orientation framework provides a more nuanced understanding of how leaders position empathy in STEM education, revealing both tensions and synergies and evoking further discussion regarding the defining characteristics of STEM education. A cohesive collective understanding of empathy's role remains underway, highlighting the need for enhanced professional dialogue among diverse STEM education stakeholders.

Keywords: Empathy; STEM education; Education leader; Thematic analysis

Introduction

"Act in such a way that you treat humanity... always at the same time as an END (aim) and never merely as a MEANS (tool) to an end." —Immanuel Kant (1785)

The role of empathy in STEM education represents one of the most contested areas in contemporary educational discourse (Sun, 2017). As STEM education evolves globally, a fundamental tension has emerged: should empathy serve primarily as a tool to enhance technical learning outcomes, or should it be integrated as a core aim of STEM education itself? This tension reflects broader debates about the purpose of STEM education in society and the Nature of Science (NOS) (Lederman, 2013; Wieder, 2006).

Historically, debates regarding the extent to which science should maintain strict objectivity versus incorporate personal values have been substantive (Lacey, 2005; Longino, 1990). Traditional perspectives characterized science as objective and independent of human and societal factors, thereby minimizing potential personal bias and enhancing accuracy and reproducibility (Proctor, 1991). These prominent characterizations of science once led to a prevalent assertion that "Good science is value-free" (Longino, 1983, pp. 15-16). While contemporary scholarship largely rejects this view (Ambrosj et al., 2022; Chen & Sonnert, 2024), this legacy perspective continues to influence some STEM educators, creating ongoing tension regarding the integration of values.

In contemporary discourse, STEM educators have increasingly challenged this value-free assumption, arguing that the integration of personal and social values into NOS conceptualizations is both inevitable and essential (Ambrosj et al., 2022; Edelen et al., 2024), as evident in diverse NOS frameworks (Abd-El-Khalick et al., 2017; Erduran et al., 2014; 2023). Specifically, the integration of values into STEM education often necessitates empathy as a foundational element. Empathy serves as a necessary catalyst for pro-social behavior and moral

development (Makal & Çepni, 2024) and has been at the heart of school curricula globally to promote learning persistence (Goleman, 1996; OECD, 2019). Taking chemistry, for example, teaching chemistry as a tool for greater purposes, such as cooking food to feed others (also known as kitchen chemistry), is associated with stronger science identity and career interests (Chen et al., 2024). However, when considering empathy's role in STEM education specifically, two contrasting perspectives emerge. One views STEM education as an integral part of holistic education and thus a natural domain for cultivating empathy. The competing perspective questions this integration, arguing that STEM's primary focus should remain on technical competencies while other disciplines bear responsibility for empathy cultivation. This fundamental tension raises an important question: How do STEM educators view the role of empathy in practice?

Indeed, STEM educators, particularly in Western regions, increasingly urge empathy's vital role in diverse aspects of STEM education reform (Jackson et al., 2021; Zeyer, 2018), notably in movements promoting more inclusive and humanized STEM environments (Yao et al., 2023). In Asian contexts, where education systems have historically emphasized pro-social values, a clear division has existed between STEM subjects and the humanities in traditional curricula (Fensham, 2008; Gough, 2015), albeit with an increasing intersection of these fields (Cheung, 2020; Han & Wei, 2024). Eastern cultures emphasize pro-social values but traditionally separate STEM from humanities, contrasting Western integrative approaches (Fensham, 2008). In Hong Kong's hybrid context, this manifests as tension between exam-driven technical focus and emerging value integration, influencing empathy's positioning amid cultural resistance to affective elements in 'hard' sciences.

Despite growing calls for such values, the role of empathy has rarely been explicitly stipulated in major STEM education reforms. If we simply ask if empathy is important, we anticipate

favorable ratings; however, we have very limited knowledge of how STEM education leaders view the role of empathy and whether a consensus exists. Wilson and Mukhopadhyaya's (2022) study of North American engineering professionals found a wide and concerning division regarding empathy's inclusion as a core competency. How do STEM education leaders position empathy in STEM education? Are they as divided as engineering professionals? The answer may largely enrich our understanding of empathy's role exclusively through the lens of leading practitioners.

As of 2024, the Hong Kong Education Bureau has implemented a significant overhaul of primary and secondary STEM/science curricula (Curriculum Development Council, 2024a; 2024b). A key innovation in this new curriculum is the integration of socio-scientific issues (SSI), which emphasizes social and human factors in scientific investigation as a cognitive reasoning skill—though empathy itself remains implicit. SSI serves as a paradigmatic example where empathy plays a crucial, explicit role in STEM, highlighting recent advancements toward societal and environmental discussions. However, empathy's integration extends beyond SSI; for instance, design thinking frameworks position empathy as a starting point even in non-social contexts, moving STEM away from pure solutionism toward human-centered problem-solving across topics.

STEM education leaders serve as key stakeholders in policy development, and their views directly influence ongoing curriculum reform in Hong Kong. More importantly, their perspectives also offer valuable insights beyond local contexts. Hong Kong represents a unique educational environment where Eastern and Western pedagogical approaches intersect, making it an instructive case study for global STEM education discourse. The challenges of integrating humanistic elements into traditionally technical disciplines are widely shared, though solutions must be culturally responsive. As Asian education systems and beyond increasingly incorporate

socioscientific reasoning into STEM curricula, Hong Kong's approach may provide comparative insights.

Therefore, this study uses the Hong Kong context to investigate how a diverse cohort of STEM education leaders views the role of empathy in STEM education. To answer this question, we interviewed a representative sample of STEM education leaders in Hong Kong spanning university faculty, secondary and primary school science/STEM teachers, and out-of-school STEM education providers.

Literature Review

Empathy in General Education: Foundations for STEM Integration

Empathy is a multifaceted construct evolving from an analytical tool for interpersonal recognition (Zeyer & Dillon, 2019) to a mechanism encompassing emotional contagion and cognitive/emotional reactions. Traditional definitions characterize it as an emotional response stemming from comprehension of another's emotional state (Eisenberg, 2000). Recent neuroscience research dissociates empathy into emotional aspects (experiencing others' feelings) and cognitive aspects (recognizing others' emotions and understanding their thoughts) (Dvash & Shamay-Tsoory, 2014; Yoon et al., 2020). Contemporary educational research has embraced this framework, as briefly exemplified by the Gender-Systemising-Empathising-Motivation (GSEM) Model, which links empathy to STEM learning motivation without diluting focus on cognitive aspects (Zeyer, 2018).

In educational contexts, empathy has been recognized as a fundamental goal since the 20th century (Portal, 1983). Philosophically, it serves as a foundational element for moral reasoning, ethical behavior, and responsible citizenship (Decety & Cowell, 2014; Jackson, 2014a; Waghid, 2024). Educational frameworks, such as Goleman's (1996) emotional intelligence and social-

emotional learning models (Cooper, 2011), identify empathy as a core competency, acknowledging that cognitive learning alone is insufficient for personal and social well-being.

Empirical and policy syntheses underscore empathy's benefits: it catalyzes pro-social behavior and moral growth by reconfiguring students' cognitive frameworks (Makal & Çepni, 2024; Narvaez, 2010), improves academic and social outcomes (Cooper, 2011; Eisenberg, 2000), and reduces negative behaviors (Goleman, 1996; Jackson, 2014a). Recognizing this, recent global frameworks explicitly incorporate empathy as a central aim. The OECD Learning Compass 2030 (OECD, 2019) identifies empathy as essential for navigating diverse classrooms and workplaces, and UNESCO positions it as critical for sustainable development and global citizenship (UNESCO, E, 2015). This cohesive evidence base directly informs our study's humanist orientation in STEM.

Challenges in Empathy Education

Implementing effective empathy education presents significant challenges, including its fleeting nature (Jackson, 2014a) and potential misuse without emotional engagement (Cooper, 2011). Cultural and contextual factors further complicate empathy development, requiring educators to adapt approaches to specific communities and traditions (Stellar & Duong, 2023).

The tension between explicit empathy instruction and more implicit cultivation through contextual learning remains unresolved. Some scholars advocate for dedicated empathy curricula (Goleman, 1996), while others suggest that authentic experiences and relationship-building represent more effective approaches (Jackson, 2014b). This tension mirrors broader debates regarding the balance between direct instruction and experiential learning.

This general foundation informs empathy's integration in STEM, aligning with our study's aim to explore its dual roles through utilitarian and humanist lenses. Building on these general insights,

we now focus on empathy's specific role in STEM education, addressing our research aims by examining historical exclusions and recent integrations.

Empathy in STEM Education

Historically, the relationship between empathy and STEM education has been characterized by separation and occasional antagonism. Traditional perspectives characterized science as objective, neutral, and value-free, thereby reducing the risk of personal bias and improving both accuracy and reproducibility (Proctor, 1991). These notable descriptions of science once gave rise to a widespread claim that "Good science is value-free" (Longino, 1983, pp. 15-16), which excludes social and emotional elements such as empathy in science and STEM education even in an unconscious manner. This historical assertion, though outdated, helps explain divergent views among STEM practitioners and educators, where some may still echo this perspective.

Guney and Seker (2012) documented how science education historically separated cognitive learning from affective dimensions, creating what they termed a "false dichotomy" between knowing and feeling. This separation aligned with prevailing notions of scientific objectivity that dominated much of 20th-century STEM education (Longino, 1990). The historical emphasis on STEM disciplines as value-neutral has resulted in pedagogical approaches that prioritize abstract concepts and procedural knowledge over human-centered considerations (Zeyer & Dillon, 2019).

Recent Integration: Challenging the Value-Free Assumption

In current conversations, STEM educators are increasingly disputing the idea that science is devoid of values, instead calling for rethinking the role of empathy in STEM education. STEM educators, particularly in Western regions, increasingly argue and investigate the role of empathy in STEM education from diverse perspectives. For example, Zeyer (2018) utilized the Empathizing-Systemizing Theory to investigate the potential association between gender and

motivation to learn science and STEM; Yao et al. (2023) argued for an empathy-based STEM culture for humanizing STEM education that is more inclusive to all students; Zeyer and Dillon (2019) claimed that including empathy in socio-scientific issues within STEM education is "not only useful but actually vital" (p. 297).

Empirically, increasing studies examining empathy's role in STEM education have yielded promising but nuanced findings. Bush et al. (2020) discovered that empathy was a key component of students' STEAM experiences, reaching a level that led to transformative learning. More specifically, by participating in empathetic problem-solving, students were able to recognize the subjective nature of engineering, thereby engaging in authentic STEM practices. Li et al. (2024) noted a significant impact of empathy on students' creativity in design thinking, which is essential for effective problem-solving in STEM education.

Social justice applications of STEM education have demonstrated particular benefits from empathy integration. Trott et al. (2023) found that empathy-centered climate change education enhanced students' climate justice awareness and action orientation. Nalipay et al. (2024) demonstrated that in STEM programs incorporating community service learning, students' empathy positively influenced their desire for community involvement, which in turn enhanced their perseverance in STEM learning. These findings suggest that connecting STEM education to human needs through empathy can enhance both STEM learning and social engagement.

Promising Changes and Challenging Reforms

Embracing these efforts, a reconceptualization of the Nature of Science (NOS) is in progress, emphasizing that incorporating values into its framework is not only inevitable but also essential (Ambrosj et al., 2022). This is evidenced in frameworks such as the Social and Cultural Embeddedness of Science aspect in the Ten-aspect NOS framework (Abd-El-Khalick et al.,

2017) and the Social-Institutional aspects in the Family Resemblance Approach to NOS (Erduran et al., 2014). This reconceptualization of NOS underscores empathy's potential as a bridge between objective scientific inquiry and value-laden societal applications, challenging traditional value-free assumptions by embedding affective elements like empathy into STEM's core epistemological framework.

Beyond the NOS conceptualization, integrating values into STEM learning has gradually become a focus in STEM education reform, particularly in Western regions. In Asian regions, although education systems have historically and culturally focused on pro-social values, there has been a distinct separation between STEM subjects and the humanities in traditional curricula (Fensham, 2008; Gough, 2015). Recent education movements gradually, however, demonstrate an increasing intersection of this division and more explicit emphasis on social-scientific reasoning, as evidenced in new Chinese mainland high school physics textbooks (Han & Wei, 2024) and Hong Kong's biology curriculum and high-stakes assessments (Cheung, 2020). Notably, even with rising demands from the STEM education academic community in both the West and East for these values, the role of empathy has seldom been explicitly defined in key STEM education reforms.

The Analytical Lens: Empathy and the Two-fold Orientation of STEM Education

A key theoretical contribution of this study is the development of a structured analytical framework to examine empathy's role in STEM education. Based on our synthesis of existing literature, we articulate two-fold orientations of STEM education—utilitarian-oriented and humanist-oriented—that fundamentally shape how empathy is positioned in STEM educational contexts. This framework addresses a significant gap in the literature by providing a structured lens for analysing diverse perspectives on empathy in STEM education. Throughout this study, we employ this two-fold orientation as an overarching analytical lens to interpret our empirical

data.

The Utilitarian Orientation: Empathy as a Tool for Technical Competence

Since the Industrial Revolution, the imperative for "more STEM workers" has profoundly shaped perceptions of STEM education's value (McComas & Burgin, 2020). In the United States, mainstream discourse has predominantly framed STEM education's purpose as maintaining global economic competitiveness (Garibay, 2018). This economic-centric perspective has defined both educational goals and metrics of student success, measuring achievement primarily through STEM proficiencies and degree attainment (Garibay, 2015). At its core, this utilitarian orientation prioritizes developing students' technical capacities for specific workforce demands.

Under this utilitarian framework, STEM education has concentrated on building knowledge and "hard" cognitive skills (Lamb et al., 2015), leaving limited space for broader learning objectives such as social-emotional development and empathy cultivation (Garner et al., 2018). Within this paradigm, empathy typically appears only implicitly or as a secondary outcome of cognitive learning objectives (Schiepe-Tiska et al., 2021).

With the goal of cultivating future STEM professionals, researchers have examined students' motivation for STEM learning. Theoretically, Empathizing-Systemizing (E-S) theory (Baron-Cohen et al., 2005) suggests that students' science learning motivation stems from either their tendency to understand physical systems (systemizing) or their ability to perceive others' mental states (empathizing). Research has consistently shown that systemizing significantly impacts science learning motivation while empathizing's effect has been less evident (Zeyer, 2012). However, Zeyer (2018) revealed important disciplinary variations: while these patterns hold for physics and chemistry, neither systemizing nor empathizing significantly influences biology motivation. This nuanced relationship suggests that traditional science pedagogy may overlook

the needs of empathizers, potentially missing opportunities to encourage their pursuit of science (Zeyer & Dillon, 2019). We reference E-S and GSEM selectively here to illustrate empathy's motivational role, directly supporting our utilitarian framework without unrelated elaboration. Drawing from NOS perspectives (e.g., Abd-El-Khalick et al., 2017), the utilitarian orientation aligns with NOS tenets that emphasize empirical rigor, while integrating empathy as a tool enhances systemizing without diluting scientific objectivity.

More recently, Maiorca et al. (2021) proposed empathy as a potential bridge between informal STEM learning experiences and STEM career interest, with preliminary qualitative findings suggesting empathy may influence career aspirations—a relationship warranting further investigation. This positions empathy disregard as a STEM-wide issue, with engineering as an illustrative case, but similarly affecting motivation in biology (e.g., ethical research) and physics (e.g., societal applications of technology).

Empirical studies examining the utilitarian value of empathy have also documented mechanisms through which empathy enhances multiple STEM learning outcomes. While engineering design often exemplifies this (e.g., Yeung & Ng, 2024), empathy's instrumental role extends to other STEM fields; for instance, in biology, empathy aids in understanding ecological systems and ethical animal research (Zeyer, 2018), and in physics, it facilitates real-world applications like sustainable energy solutions by considering user needs (Trott et al., 2023). This positions empathy as a broad STEM tool, with engineering serving as a representative case due to its emphasis on problem-solving. Liu et al. (2024) demonstrated that primary students engaged in empathy-based design thinking developed more creative and effective solutions to engineering challenges. McCurdy et al. (2020) documented how problem-based design thinking tasks incorporating empathy enhanced student engagement and technical understanding simultaneously.

The Humanist Orientation: Empathy as an Educational Aim

Despite the dominance of the utilitarian orientation, critics increasingly challenge these stereotypical STEM education paradigms where "socio-political silence" pervades policy frameworks (Chesky & Wolfmeyer, 2015). Critical scholars assert that STEM education should transcend superficial economic impact considerations and fundamentally incorporate humanist values (Ortiz-Revilla et al., 2020). This perspective posits that STEM education should broaden its impact on human welfare, ultimately fostering a more democratic, equitable, and sustainable society (Letizia, 2016). Consequently, students are expected to comprehend challenging socio-scientific issues through their STEM knowledge and engage in responsible action toward a more sustainable and just world (Castano, 2008; Gough, 2015). In contrast to utilitarian orientation, this critical perspective offers an alternative approach: humanist-oriented STEM education (Ortiz-Revilla et al., 2020).

Following this orientation, scholars argue that STEM education should be value-driven rather than maintaining strict objectivity or subordinating itself to economic imperatives (Chen et al., 2023). Ortiz-Revilla et al. (2020) contend that STEM education, as an educational strategy, inherently shares responsibility for general education's philosophical objectives: universal student education and future society construction (Schiff et al., 2025). Consequently, integrated STEM curriculum and pedagogy should prioritize social and cultural meaning, pursuing social justice through comprehensive technoscientific literacy (Ortiz-Revilla et al., 2020).

More pressingly, Visintainer (2022) critiques the inclination toward illusory objectivity that perpetuates disguised bias and potentially exacerbates harm. Chen et al. (2023) argued that the civic ideas in science curricula afford rich opportunities and also pose critical challenges that are too significant to be ignored by science educators or simply brushed off in civics curricula. For example, Donovan (2017) observed that repeated exposure to racial terminology in biology,

based on traditional value-neutral pedagogy, increases bio-behavioural essentialism and prejudice. Instead, evidence suggests that intentionally equity-based discussions of false race-genetics linkages help prevent erroneous social identity beliefs (Donovan et al., 2020, 2021). Students naturally make romantic transfers, and instead of leaving them unsupervised, teachers should take them as social-scientific investigation opportunities (Chen et al., 2023).

Inspiringly, social justice issues increasingly permeate STEM education discussions, with particular emphasis on climate justice in recent years (Porter et al., 2020; Schlosberg & Collins, 2014). Empirical studies demonstrate STEM education's efficacy in generating support for climate justice, enhancing children's climate change ownership, and addressing climate inequities (Tagg & Jafry, 2018; Trott et al., 2023). Following these trends, STEM education progressively aims to develop core competencies necessary for full citizenship in a future society (UNESCO, E, 2015). This exemplifies humanist-oriented STEM education's core principles.

Notably, incorporating such values necessitates prioritizing empathy as an initial step, given its foundational role in moral development and cognitive transformation (Makal & Çepni, 2024). Empirical research supporting the humanist orientation has documented how empathy-centered STEM education can produce broader educational outcomes. Ampuero et al. (2015) found that incorporating empathy into environmental education enhanced students' sustainability-oriented action competence. Almers (2013) identified empathy as one of six critical pathways through which students develop the capacity to address complex sustainability challenges. Teo et al. (2024) demonstrated that inclusive design activities along with empathy in STEM contexts significantly enhanced students' social empathy development. To sum up, empathy transcends its status as a byproduct or side effect to become a significant educational aim, particularly in the STEM domain.

Diverse Perspectives and Synthesis

We approach empathy from a balanced perspective, integrating utilitarian and humanist orientations. Recent research has begun reintegrating empathy into STEM education through various approaches that position it as both a means and an end. We use specific frameworks—Design Thinking, Socio-Scientific Issues (SSI), and STEAM/STREAM—as examples of recent advancements that explicitly embed empathy. These frameworks cover major STEM problem statements (technical, social, creative), illustrating empathy's broader role in STEM, not constraining it to specific criteria but enabling integration in diverse contexts to foster holistic learning.

Design thinking is prominent, particularly in engineering and product design, but its principles apply broadly across STEM (e.g., chemistry for user-centered product development). The five-phase design thinking model explicitly establishes "empathize" as the foundational stage (Kelly, 2001). Empathy functions dually: as a utilitarian tool for creating better solutions by understanding end-users, and as a humanistic aim by reorienting problem-solving around human flourishing rather than technological opportunity (Walther et al., 2017). Design thinking is also a powerful framework for social innovation.

SSI, as mentioned above, provides a parallel framework focused on social-environmental problems, where empathy is crucial for understanding diverse perspectives and promoting social justice (Trott et al., 2023).

STEAM/STREAM approaches integrate arts and humanities, fostering creativity and emotional expression (Bush et al., 2024). Empathy in STEAM/STREAM enhances artistic outcomes (e.g., empathetic aesthetics) and ethical reflections, prioritizing emotional/humanistic integration beyond utilitarian tools (Yao et al., 2023).

Project-Based Learning (PBL) serves as an overarching pedagogy that synthesizes these

approaches by engaging students in solving authentic problems (Kokotsaki et al., 2016). Whether the context is product design (Design Thinking), social-environmental issues (SSI), or artistic/humanist projects (STEAM/STREAM), PBL requires students to understand the context and stakeholders involved. Empathy is therefore critical in PBL across all STEM disciplines—including theoretical fields like mathematics—as it bridges abstract concepts with real-world human needs (Boss & Krauss, 2018; Maiorca et al., 2021). For instance, mathematics students can employ PBL to model social inequities or environmental data, fostering emotional connection to the problems.

Various frameworks, often implemented through PBL, illustrate empathy's versatility across STEM. Several studies suggest this dual role of empathy. Kijima et al. (2021) found that students engaged in design thinking developed both technical skills and pro-social tendencies. Bush et al. (2024) documented how humanistic STEM instruction through empathy enabled students to address community needs while developing technical competencies. These examples were selected as representative advancements explicitly embedding empathy, without excluding other approaches.

Critical Perspectives: Tensions and Debates in Empathy Integration

As educators increasingly prioritize values such as empathy in STEM education, concurrent concerns emerge regarding science's potential deviation from its inherent neutrality. The controversial Sokal Hoax affair, for instance, made an irony of the romanticized transference of scientific theories into humanistic domains (Hodge, 1999; Sokal, 2010). McComas and Burgin (2020) express concern that the "quick fixes" for the lack of value in STEM or advocacy for the "next big thing" as a fashionable movement purported in some of the value-driven initiatives may compromise the fundamental teaching of STEM either as a subject matter knowledge or a method.

Regarding empathy specifically, Zeyer and Dillon (2019) identify two historical misconceptions in both science and humanities domains. The first posits empathy as an alternative or antithesis to scientific thinking; the second presents empathy as the exclusive methodology of human sciences. Both assertions contributed to an untenable yet once widely accepted scientific philosophy: "Good science is value-free". From this retrospective perspective, Zeyer and Dillon (2019) advocate for more serious and consistent inclusion of empathy in science and STEM learning while maintaining appropriate caution.

The literature also reveals tensions regarding how empathy should be positioned within STEM educational systems. Some scholars advocate for disciplinary integration approaches like STEAM or STREAM (Bush et al., 2024). Empathy aligns by enhancing artistic outcomes in STEAM (e.g., empathetic design in visual arts) and ethical reflections in STREAM, differing from pure STEM by explicitly prioritizing affective domains over technical focus. However, some scholars warn against undiscriminating expansion that might dilute disciplinary integrity (McComas & Burgin, 2020). Some researchers emphasize explicit empathy instruction (Nalipay et al., 2024), while others suggest more implicit integration through context-rich STEM problem-solving (Hwang, 2022). Cultural and contextual factors further complicate these debates, with evidence suggesting that empathy development strategies must be adapted to specific educational traditions rather than imposed universally (Schaffar & Wolff, 2024).

Divisions in Viewing the Role of Empathy and the Research Gap

Despite the aforementioned diverse perspectives and specific insights highlighted within the STEM education academic community, our understanding of how key STEM education leaders collectively view the role of empathy in education reforms—both locally and globally—remains very limited. This is particularly important given that the role of empathy has rarely been explicitly defined in major STEM education reforms across the globe, which undermines its

potential to influence curricula and teaching practices.

Furthermore, research has evidenced a significant division in viewing the role of empathy among the group of engineers (Wilson & Mukhopadhyaya, 2022). Wilson and Mukhopadhyaya (2022) systemically analyzed the literature on empathy in engineering education in North America and synthesized the data to present engineers' views of empathy's role in education and practice. Their study revealed a range of divergent insights. Some believe that the profession is inherently empathetic; some recognize the significance of empathy but are reluctant to include it as a core competency of engineers; some even support a tendency to undervalue empathy within engineering because they suppose it is not their job to be empathetic or caring. The extent to which this considerable division applies to STEM educators is unknown.

This research gap highlights the need for empirical investigation into how diverse STEM education stakeholders view the role of empathy. By examining perspectives from university faculty, school-based educators, and out-of-school STEM education providers, we can develop a more nuanced understanding of how empathy is positioned within STEM education and identify both tensions and synergies that emerge across different professional contexts. This study addresses this gap by applying our two-fold orientation framework to analyze how a diverse cohort of Hong Kong STEM education leaders view empathy's role in STEM education.

More specifically, we address the following two specific research questions:

1. To what extent do their views align with utilitarian versus humanist orientations?
2. What tensions or synergies emerge from different groups of leaders in understanding empathy's role in STEM education?

This Study and Methods

Contexts

Traditionally, social values, including empathy, have been emphasized in humanities curricula in Hong Kong, for example, Citizenship, Economics, and Society for secondary schools (Curriculum Development Council, 2024c) and General Studies for primary schools (Curriculum Development Council, 2017). As of 2024, the Hong Kong Education Bureau has initiated a major curricular reform, actively seeking advice on how to incorporate societal and human factors into STEM and science curricula (Curriculum Development Council, 2024a; 2024b). In particular, the Curriculum Development Council (2024a) has recently released the consultation draft of the Science (Secondary 1-3) Curriculum Framework for public advice, which newly incorporates socio-scientific issues to strengthen cross-disciplinary connections. In this ongoing reconceptualization of STEM education in Hong Kong, local STEM education leaders, as key stakeholders, are actively involved and consulted.

Significance

We investigate how STEM education leaders view the role of empathy in STEM education. This study makes three significant contributions to the field:

- **Theoretical contribution**: We develop and apply a novel analytical framework based on two-fold orientations in STEM education (utilitarian and humanist) that provides a structured lens for analyzing diverse perspectives on empathy. This framework also further addresses a significant gap in the existing literature by moving beyond binary approaches to understanding empathy's role in STEM education, providing a foundation for future research in this area.
- **Empirical contribution**: This study represents the pioneering systematic investigation of

how diverse STEM education leaders view empathy's role in STEM education. By examining perspectives across different professional contexts (universities, schools, and external organizations), we reveal patterns of agreement and disagreement that illuminate the complex nature of empathy integration in STEM education.

- **Practical contribution**: Our findings directly inform ongoing debates about empathy's place in STEM curriculum development. By identifying specific tensions around disciplinary boundaries and documenting consensus areas regarding empathy's instrumental value, this study provides concrete guidance for curriculum developers seeking to integrate empathy in contextually appropriate ways.

This research leverages Hong Kong's unique position at the intersection of Eastern and Western educational traditions to illuminate broader global patterns in how empathy is positioned in STEM education. The tensions we identify between disciplinary integrity and humanistic integration transcend local contexts, reflecting fundamental challenges faced by educational systems worldwide as they navigate the evolving purpose of STEM education in society. By examining these dynamics through the lens of a diverse stakeholder group, this study offers insights applicable to international STEM education reform efforts.

Participants and Data Collection

This study is part of a key project aimed at gathering comprehensive advice on establishing a performance expectation framework for STEM education among primary and secondary school students in Hong Kong. We invited twenty-six STEM education leaders from Hong Kong, representing four distinct panel groups: universities, secondary schools, primary schools, and out-of-school STEM education organizations. The university representatives are drawn from three leading education faculties in Hong Kong. The teachers from primary and secondary

schools possess extensive teaching experience, with half holding prominent positions like presidents. Leaders from out-of-school organizations are at the forefront of influential extracurricular STEM education providers. They serve as the leaders of STEM-associated professional or charity societies, providing regular and extracurricular STEM education to the public or schools. Due to the limited time and manpower in regular schools in Hong Kong, many STEM programs are delegated to out-of-school education providers (Ma & Chung, 2020). Despite the diversity of the panel groups, these leaders collectively play a significant role in shaping STEM education policy and providing leadership counsel in Hong Kong. In the current study, we specifically focus on the empathy aspect and analyse the relevant data derived from our extensive collection efforts.

Specifically, these leaders rated the importance of empathy in the Hong Kong STEM education framework on a scale of 1 (strongly disagree) to 5 (strongly agree). The average score was 3.77 (SD=1.22), with most responses clustering around 4 and 5 (5 accounting for 26.92%, 4 for 46.15%, 3 for 15.38%, 2 for 3.85%, and 1 for 7.69%). The distribution indicated a general agreement that empathy was moderately or strongly important in STEM education. This motivated us further to explore the variation in the justifications (not just the agreeability) for the importance of empathy. Thus, we then conducted individual interviews with twenty-two leaders, as four opted out of the interviews. Among those interviewed, five leaders provided overly brief responses, even after requests for elaboration. Consequently, our analysis centers on the detailed insights of the remaining 17 leaders in this study: five (three male, two female) are STEM education researchers from universities; nine are experienced and leading school STEM teachers—five (four male, one female) in secondary and four (three male, one female) in primary sectors; and three (two male, one female) are out-of-school STEM education providers. Each leader possesses over ten years of professional experience, particularly in teaching.

The interview protocol (particularly relevant to the empathy aspect) mainly consists of the following interview questions: in STEM education, 1) What issues (at personal, social, and global levels) do you think are important for STEM education? And why? 2) What are the attitudes or values you think are important for STEM education? And why? 3) What do you think is the role of empathy in STEM education? And why?

The first two questions were intentionally broad to allow participants to freely articulate their views on important issues, attitudes, and values in STEM education without priming them toward empathy. This design avoids bias, as explicit focus on empathy might elicit uniformly positive responses (as noted in the literature, e.g., Wilson & Mukhopadhyaya, 2022). Participants were first invited to consider the full range of performance expectations and objectives in STEM education. By presenting this "full plate" of diverse outcomes within the busy schedule of the STEM curriculum, we encouraged them to situate empathy in relation to competing priorities. This approach allowed participants to position empathy as central, peripheral, or even absent from STEM education, thereby enabling diverse perspectives to emerge authentically. No probing questions primed specific topics (e.g., design thinking); insights emerged authentically from participants' open-ended responses, indicating their unprompted associations with empathy in STEM contexts.

Data Analysis

In the data analysis phase, we followed the thematic analysis, a qualitative coding analysis, proposed by Mirhosseini (2020). The coding process consists of four main stages: initial coding, focused coding, axial coding, and theoretical coding. The initial coding aims to identify any relevant elements possibly related to the research question. "Initial codes" emerge in this first stage.

During the focused coding process, we pay attention to the relatedness, similarity, or sameness of individual codes, and the reduced bodies of data are now put into meaningful categories. Under the context of our study, we intentionally refer to the selected theoretical lens in the focused coding, namely, the two-fold orientations of STEM education. Two major themes emerged corresponding to the two orientations, respectively. The first theme, "tool", corresponds to the Utilitarian Orientation, indicating the "tool" role of empathy in STEM education. The second theme, "aim", corresponds to the Humanist Orientation, indicating that empathy serves as the aim of STEM education. The broad initial questions enabled emergent data on empathy's positioning, which we analyzed through our two-fold framework to address the research questions, revealing unprompted associations with utilitarian and humanist roles.

Then, the data exploration process reaches a third stage known as axial coding. Under each major theme, minor categories that address more specific concerns related to the research question emerge. In our context, under the "tool" theme, we extract two subthemes, namely, "attention drawing" and "problem solving". Under the "aim" theme, we extract three subthemes, including "educational value", "definitional boundary", and "ultimate goal".

The theoretical coding is the final stage of answering the research question more contextually. We present the coding scheme, including themes, subthemes, and corresponding descriptions in Table 1. To enhance traceability and cross-group comparisons, we summarize key participant responses in Table 3, linking subthemes from Table 1 to individual views and addressing RQ2 on tensions/synergies. Besides, we also included quotes of each subtheme within both positive and negative positions, if any, as part of the theoretical coding outcome.

(Table 1 is inserted here)

Regarding the trustworthiness of these qualitative data, two authors collectively proposed the coding scheme, and all authors reviewed and discussed it to ensure its appropriateness for the study. Two of the authors specializing in STEM education independently coded the data to minimize individual bias. We calculated Cohen's Kappa, which yielded a value of 0.86 ($p < 0.001$), indicating strong agreement between the coders (McHugh, 2012). We then discussed and resolved any discrepancies that arose during the independent coding process.

Reflexivity

As researchers, we regard empathy as a crucial driver in STEM education, consistent with recent scholarship emphasizing that value-integrated STEM fosters holistic outcomes, whereas neglecting ethical and human-centered dimensions can cause harm. To mitigate both potential bias in our interpretations and undue influence on participants, we implemented specific methodological strategies. Recognizing that virtually no educators would openly dispute the importance of empathy, we deliberately designed broad initial interview questions that avoided priming participants toward endorsing it (explained above). Furthermore, we analyzed data independently with inter-coder reliability (Cohen's Kappa 0.86) to curb subjectivity.

Results

Two primary views of empathy's role in STEM education emerged from the data: empathy as a "tool" (utilitarian orientation) and empathy as an "aim" (humanistic orientation).

Empathy as a Tool of STEM Education

Empathy as an Attention-Drawing Mechanism

Leaders viewed empathy's role in capturing student attention during STEM learning differently,

revealing a spectrum from sustained contextual themes to brief introductory hooks.

One secondary school leader (S1) positioned empathy as a substantial contextual framework that could sustain student engagement throughout entire learning units or courses: "Empathy is often important and manifested in health-related issues...My personal experience is that health-related issues are quite important. As our school is a girls' school, women students are all interested in these topics, such as medical care, biology, and health management. I suppose the health-related issues should be a big part of STEM learning." This perspective suggests empathy serving as a thematic anchor aligned with students' existing interests, with this leader specifically noting potential gender considerations in STEM engagement through deliberately chosen empathy-rich contexts.

In contrast, a primary school leader (P2) characterized empathy as a tactical introductory element—an initial "hook" to spark interest in otherwise technical content: "If only pure STEM elements existed, it would be a bit bland and boring. If you use real estate tycoons as a starting point, students may gain more experience or understanding. I think providing students with a caring attitude for others, namely empathy, is completely right." This view positions empathy as a pedagogical strategy for making technical content initially accessible, rather than as a sustained thematic framework.

These contrasting perspectives reflect different approaches to leveraging empathy's motivational power in STEM learning. While one leader sees empathy-rich contexts as sustained themes that can connect with students' interests throughout a learning experience, the other views empathy as a strategic entry point to engage students at the beginning of instruction. Both recognize empathy's capacity to draw attention, though they conceptualize its implementation at different scales and durations within the instructional sequence.

Empathy as a Procedural Tool for Problem Solving in STEM Design

Six leaders across four diverse panel groups identified empathy as a functional component within the STEM design process, specifically positioning it as a procedural tool for effective problem solving. These leaders emphasized empathy's role in addressing the practical "how" dimensions of design challenges rather than focusing on broader aims or values (such as “who” or “why”).

Multiple leaders characterized empathy as an essential starting mechanism for the design process. A secondary school teacher (S2) highlighted this initiating function: "I think empathy is very important; this is where they start to think about how to initiate STEM design and further serve society." Similarly, a primary school leader (P1) articulated empathy as a procedural catalyst that drives specific design considerations: "I think if the students want to do something, they basically need to have empathy, that is, doing something for others; only in this way will they be able to think more specifically about how to design and what products would be helpful to help others."

This procedural framing extended to problem identification, with an out-of-school STEM education provider (O1) describing empathy as instrumental in defining meaningful engineering challenges: "We try to use a little bit of technology to help solve this problem, but first, he has to identify a problem and understand how we expect to solve it. In this process, you have to have empathy and understand the needs of others through special activities. When you design a product, you must be able to help the other person."

A university leader (U1) positioned empathy as a functional requirement within design thinking methodology: "Actually, without this kind of care, you would not develop the empathy required in design thinking for STEM education." This characterization frames empathy not as an educational aim itself, but as a necessary cognitive tool within the design thinking framework.

These perspectives collectively position empathy as a practical problem-solving instrument within the STEM design process—a methodological approach that enhances students' ability to identify problems, conceptualize solutions, and develop effective designs. By focusing on the "how" of design work, these leaders framed empathy as a cognitive tool that drives the technical aspects of STEM problem-solving rather than serving primarily as a humanistic educational aim. This functional conceptualization suggests empathy serves as a bridge between human needs and technical solutions, enabling more targeted and effective design approaches within STEM education.

Empathy as the Aim of STEM Education

Empathy in Defining the Boundaries of STEM

Empathy as an Expansion of STEM's Definitional Boundary

Several leaders advocated for fundamentally redefining STEM to include humanities, positioning empathy as an essential expansion of what STEM education should encompass. This perspective challenges traditional definitions that emphasize technical disciplines in isolation from human concerns. A primary school leader (P3) cautioned against narrowly technical definitions: "Students often tend to develop a specific technology product to help the old, but seldom really visit and accompany them. Without sincere caring for and empathy with others, STEM would be quite 'cold'." This suggests that defining STEM without empathy produces an incomplete educational framework.

Similarly, a secondary school leader (S3) proposed a definition of STEM that consistently incorporates empathy across educational levels: "Empathy and caring for others is always the key... The percentage of humanity elements is a big difference between middle and high school... but whatever grades, caring for others is repetitively stressed and gradually deepened." This

indicates a view that empathy should be a defining characteristic of STEM education, not an optional supplement.

An out-of-school STEM education provider (O2) articulated an even more expansive redefinition: "Often, the issues in STEM activities are related to history, economy, and even psychology... Sometimes STEM can become STEAM and even STREAM, in which the R indicates religious...empathy can, of course, play a role…" This perspective proposes fundamentally redefining STEM to create new acronyms that explicitly acknowledge empathy's role in expanding disciplinary boundaries.

These boundary-expanding perspectives share a conviction that any meaningful definition of STEM education must incorporate empathy as a core component, not merely as an add-on to technical subjects.

Empathy as a Potential Distraction from STEM's Definitional Clarity

In contrast, several leaders expressed concern that incorporating empathy into STEM's definition risks diluting its disciplinary integrity and distinctive educational contribution. These leaders advocated for maintaining clearer definitional boundaries. A university leader (U2) questioned whether empathy should be included in how we define STEM: "I think this is too generic. It can exist on many sides, so why must we do it in STEM?... I can't understand the relationship between empathy and STEM. I think both moral and civic education can achieve this..." This suggests that expanding STEM's definition to include empathy might blur important distinctions between educational domains.

Two out-of-school STEM education providers expressed similar definitional concerns. One (O1) noted: "Developing empathy is not limited to STEM education. In fact, many disciplines can achieve this," suggesting that definitional boundaries should maintain disciplinary

distinctiveness. Another (O3) cautioned: "Empathy is important but is quite broad and can be achieved in other disciplines. It would be quite difficult if this is perceived as the main aim," indicating concerns about definition creep.

More pointed critiques came from university leaders concerned about maintaining clear definitional boundaries. One (U3) argued for disciplinary specificity in STEM's definition: "When we talk about STEM, it must have its own characteristics, which is why other disciplines cannot... empathy, is a human instinct." Another (U4) warned against definitional dilution: "When we define the learning scope... we cannot extend STEM to an infinite extent and then call all the learning STEM. This may also confuse both teachers and students."

These boundary-protecting perspectives reflect tensions around how STEM should be defined, suggesting concerns that empathy-centered definitions might compromise the clarity and focus that give STEM education its distinct identity and purpose.

Empathy as an Ultimate Goal in STEM Education

Empathy as a Catalyst for Social Service

Several leaders, particularly from primary and secondary school panels, positioned empathy as a catalyst for social service, framing this as a central aim that should define STEM education's ultimate purpose. A secondary school leader (S1) described a developmental progression: "Empathy is particularly essential for older students…When students are young, their interest in STEM seems more important. But as they grow up, more emphasis should be put on their intention to help others and serve society; initially, maybe it is about themselves only, and then it expands to the community, Hong Kong, and the whole country."

Another secondary school leader (S2) articulated a similar trajectory: "I think the focus of STEM education is to examine whether or not students can apply the interdisciplinary knowledge they

have learnt to problem-solve, thereby optimizing their own lives as well as helping others. Namely, gradually from me to we, solve the problems shared by the society and world…empathy with others should play a role…"

These perspectives position social service as the ultimate purpose that should define STEM learning, with empathy serving as the motivational force driving students toward community-oriented problem-solving.

Empathy as a Possible Off-Tracking of STEM Focus

Countering the social service orientation, one university leader (U4) cautioned against locating STEM education primarily through empathy. While acknowledging empathy's role in certain contexts—"Design a good place for rough sleepers to sleep or make them feel cooler. For such a task, you may involve the science element, and then maybe you add more ethical considerations"—the leader argued against making it central to STEM's focus: "This is mainly not the teaching content of STEM Education... if you are saying that it is purely about caring for others or empathy, I do not think this is one of the most important attitudes of STEM education."

The leader further clarified: "It does not necessarily need to have human caring elements... You do not have to have this care all the time. That can also be a STEM activity." This perspective maintains that while empathy can enrich STEM activities, it should not explain STEM education's primary focus.

Empathy as the Ultimate Outcome of STEM Education

Some leaders positioned empathy not merely as a means but as the defining outcome that should characterize successful STEM education. A secondary school leader (S2) shared a compelling example: "Once, I talked with one student who participated in this project three years ago and asked what influence that project has given him till today. The student told me that a recyclable

water bottle and a recycling bag must be with him. I then really saw these two in his bag…So what impressed me most is that STEM is not purely STEM but encourages children to respond to certain needs of others through empathy." This suggests that lasting attitude changes, rather than technical skills, represent what truly defines successful STEM education.

An out-of-school STEM education provider (O2) expressed a similar priority: "So we suppose this group benefited most from that event, not in the STEM techniques but in attitudes such as empathy." These perspectives challenge conventional definitions of STEM success by positioning empathetic development as the ultimate marker of effective STEM education.

Empathy as an Educational Value

Empathy as an Absolute Creed for Education

Five leaders positioned empathy as a fundamental principle that should define educational aims, with some addressing general education and others focusing specifically on STEM. A university leader (U1) broadly noted: "Generally, all problems concerned are ultimately related to humans, not only physical environments, but a system of society. You have to have empathy." A primary school leader (P3) expressed an even stronger stance: "Empathy must be at the highest level. The reason is that if you do not help people, then what are you doing? Isn't it? Harming others is totally against the destination of all the learning, right?"

Regarding STEM specifically, another university leader (U5) emphasized: "I feel empathy is extremely crucial because the application of technology must be people-centred... applying STEM education or STEM is always person-oriented for the sake of the entire human race. So empathy is the core and the most important." A primary school leader (P4) advocated for explicit emphasis: "Maybe in the form of a self-reflection or through role play... but as for the strategic goal, I think empathy should definitely be emphasized."

These perspectives position empathy not as an optional add-on but as a fundamental value that should define the very purpose of STEM education.

Empathy as a Foundation of Value-Based Pedagogy

Two primary school leaders specifically addressed empathy's role in defining pedagogical approaches within STEM education. One (P3) contrasted school-based approaches with commercial STEM providers: "We can find quite a number of outside-school training institutions providing STEM curricula, which are often very technical and commercial... Many moral issues will arise from informal school education without sound values. So, attitudes, including empathy, must be an extreme priority, especially in the primary school phase."

Another leader (P4) advocated for explicit curriculum guidance regarding values: "Behind each STEM topic, there can be different starting points, and teachers have different values. Without any guidance or with only a very loose description, teachers can only consider the design of these activities based on their values, maybe without empathy. This is dangerous because teachers have different values or misunderstandings about certain things."

These views echo evolving NOS frameworks (Lederman, 2013; Erduran et al., 2023), where empathy expands STEM's boundaries beyond value-free inquiry to include social-institutional dimensions.

Views and Positions by Panel Groups

Based on the coding scheme, we summarized the frequencies of the diverse views and positions leaders conveyed and presented them by panel groups (see Table 2). Overall, leaders discussed empathy as an "aim" in STEM education nineteen times, while treating it as a "tool" only eight times—less than half the frequency of the former approach.

Table 2 Views and Positions by Panel Groups

Theme	Subtheme	Position	University faculties	Secondary school teachers	Primary school teachers	Out-of-school education providers	Total frequency.	
Tool	Attention drawing	+		S1	P2		2	8
	Problem solving	+	U1	S2; S5	P1; P4	O1	6	
Aim	Educational value	+	U1; U5	S4	P3; P4		5	19
	Definitional boundary	+		S3	P3	O2	3	8
		-	U2; U3; U4			O1; O3	5	
	Ultimate goal	+		S1; S2	P1; P3	O2	5	6
		-	U4				1	

To provide a clearer overview of these patterns and facilitate comparison across groups, Table 3 summarizes key participant views linked to these themes.

Our analysis reveals distinct patterns across panel groups that demonstrate how professional roles significantly influence views on empathy in STEM education:

Table 3 Summary of Key Participant Views by Theme and Group (Tied to RQ1 and RQ2)

Theme/Subtheme	University Faculty (Examples)	Secondary Teachers (Examples)	Primary Teachers (Examples)	Out-of-School Providers (Examples)	Cross-Group Comparison (Tensions/Synergies)
Tool/Attention Drawing (+)	(Minimal mention)	S1: Health issues sustain interest	P2: Hooks for engagement	(None)	Synergy: School-based groups see motivational value; university minimal.
Tool/Problem Solving (+)	U1: Catalyst in	S2/S5: Initiates	P1/P4: Drives	O1: Identifies	Consensus across all: Procedural utility

	design	STEM design	specific designs	problems	in design.
Aim/Educational Value (+)	U1/U5: People-centered core	S4: Key principle	P3/P4: Highest priority, value-based pedagogy	(None)	Tension: Primary strongest emphasis; out-of-school absent.
Aim/Definitional Boundary (+)	(None)	S3: Expands boundaries	P3: Prevents 'cold' STEM	O2: Includes humanities	Synergy: School/out-of-school support expansion.
Aim/Definitional Boundary (-)	U2/U3/U4: Risks dilution	(None)	(None)	O1/O3: Broad, not main aim	Tension: University/out-of-school cautious vs. school support.
Aim/Ultimate Goal (+)	(None)	S1/S2: Catalyst for social service	P1/P3: Defining outcome	O2: Attitude change priority	Synergy: School/out-of-school emphasizes transformative goals.
Aim/Ultimate Goal (-)	U4: Not core focus	(None)	(None)	(None)	Tension: University reluctance vs. others' endorsement.

Note: Based on frequencies in Table 2 and quotes in results; addresses RQ1 (orientations) and RQ2 (group variations).

University faculty demonstrated an unbalanced approach between empathy's dual roles, with minimal reference to empathy as a tool (only one mention) compared to five references as an aim. Despite acknowledging empathy's role as an aim, they expressed the strongest reservations about expanding STEM's definitional boundaries, with three university leaders explicitly cautioning against the potential dilution of disciplinary boundaries. As one university leader (U3) emphasized: "When we talk about STEM, it must have its own characteristics, which is why other disciplines cannot..." This pattern suggests university faculty value empathy conceptually while remaining concerned about maintaining disciplinary integrity.

Secondary school teachers exhibited the most balanced perspective, viewing empathy as both a valuable tool and an aim. Unlike other groups, they made no negative references to empathy in any capacity, indicating uniform support for empathy's integration. They particularly emphasized

empathy's procedural value in problem-solving and its role as an ultimate goal, with two positive references to each. One secondary teacher (S2) articulated this dual role: "I think empathy is very important; this is where they start to think about how to initiate STEM design and further serve society." This balanced perspective likely reflects these educators' direct classroom experience implementing STEM curricula.

Primary school teachers demonstrated a strong emphasis on empathy's role in value-based pedagogy, with multiple references to empathy as a foundational principle and exclusively focusing on value-based pedagogy in their responses. As one primary teacher (P3) asserted, "Empathy must be at the highest level. The reason is that if you do not help people, then what are you doing?" This pattern reflects primary educators' focus on holistic child development and foundational values that guide later learning.

Out-of-school STEM education providers displayed the most internally divided perspectives, simultaneously endorsing empathy as both a procedural tool and ultimate outcome while expressing concerns about its potential to distract from STEM's disciplinary focus. One agent (O3) cautioned: "Empathy is important but is quite broad and can be achieved in other disciplines. It would be quite difficult if this is perceived as the main aim." This pattern suggests that these providers must balance broad educational goals with specific disciplinary expectations in their programming.

To sum up, these distinct patterns reveal that professional context significantly shapes how STEM education leaders view empathy's role. Those working directly with students in classroom settings (particularly primary and secondary teachers) tend to emphasize empathy's broader educational value, while those in more theoretical positions express greater concern about maintaining disciplinary boundaries.

Discussion

Revisiting RQs: Positioning Empathy through Two Orientations

Our findings directly address our research questions regarding how Hong Kong STEM education leaders view empathy's role in STEM education through utilitarian and humanistic orientations.

Regarding our first research question on the alignment with utilitarian versus humanist orientations, our results demonstrate that leaders view empathy through both lenses, but with a notable emphasis on the humanist orientation. References by leaders to empathy as an "aim" (humanist orientation) occurred even more than twice as often as references to empathy as a "tool" (utilitarian orientation). This conclusion derives from thematic frequencies in results: empathy as 'aim' (humanist) referenced 19 times across subthemes like educational value and ultimate goal (Table 2), versus 8 times as 'tool' (utilitarian). Participants' unprompted responses (e.g., S2 on social service, P3 on core value) revealed the framework through emergent patterns analyzed via our two-fold lens. This suggests a significant shift beyond traditional utilitarian approaches to STEM education toward a more humanistic view.

As a tool (utilitarian orientation), leaders identified two primary functions of empathy: (1) capturing student attention through both sustained contextual themes and brief introductory hooks, and (2) facilitating problem-solving in design activities. Notably, leaders across all four panel groups recognized empathy's procedural role in design thinking (Table 3), suggesting this represents a consensus view of empathy's instrumental value.

As an aim (humanist orientation), leaders positioned empathy in three principal ways: (1) as a fundamental educational value guiding both principles and pedagogy, (2) as an essential component in defining STEM's disciplinary boundaries, and (3) as an ultimate goal of STEM education focused on social service and transformative outcomes. While leaders demonstrated

general consensus regarding empathy's instrumental role, significant disagreements emerged concerning its incorporation as an educational aim, particularly regarding disciplinary boundaries and primary focus (Table 3).

Our second research question examined tensions and synergies between different leader groups. Analysis revealed distinct patterns associated with professional roles. School-based educators (particularly at the primary level) strongly emphasized empathy's role as an educational value and aim, while university faculty and out-of-school STEM education providers expressed more cautionary views about potential disciplinary dilution (Table 3). Primary school teachers specifically highlighted empathy's importance in value-based pedagogy, reflecting their focus on foundational value development in the early education phase.

The pattern of responses suggests that leaders' professional contexts strongly influence their views of empathy’s role in STEM education. School educators, who work directly with students in implementing STEM curriculum, prioritize practical applications and value development. In contrast, university faculty and out-of-school STEM education providers, who often take broader system-level perspectives, express more concern about maintaining disciplinary integrity and boundaries. This alignment of perspectives with professional roles is consistent with research on how educational contexts shape practitioners' sense-making of educational innovations (Holmlund et al., 2018).

These findings extend beyond Wilson and Mukhopadhyaya's (2022) identification of divided perspectives among engineers to demonstrate similar patterns among STEM educators, but with a stronger overall inclination toward humanistic orientation. The prevalence of the humanist orientation suggests that Hong Kong STEM education leaders are actively reimagining STEM education as more than technical training—a shift that parallels global movements toward more value-driven STEM education while maintaining recognition of empathy's practical benefits in

design thinking frameworks (Kelley, 2001).

Revisiting Literature: Comprehensive Justifications for Both Roles

Empathy as a Tool: Utilitarian Orientations

Our findings validate key aspects of the utilitarian orientation in STEM education literature while revealing new dimensions of empathy's instrumental role. The leaders' perspectives on empathy as a "tool" align with existing research on design thinking (Yeung & Ng, 2024; Zeyer, 2018) but offer more nuanced insights into its implementation. The leaders' recognition of empathy as a "starting point" for problem-solving confirms Henriksen et al.'s (2017) framework but extends our understanding in important ways. While design thinking literature typically positions empathy as a procedural tool (Kelley, 2001), our leaders described specific and comprehensive mechanisms through which empathy enhances the design process—identify problems, conceptualize solutions, and develop effective designs. These mechanisms derived from participant responses (e.g., S2: 'start to think about how to initiate STEM design'; O1: 'identify a problem and understand needs'), elicited via broad questions without hints toward design thinking processes.

Our findings on empathy as an attention-drawing mechanism additionally support Zeyer and Dillon's (2019) concern that traditional science teaching often favors 'systemizers' over 'empathizers.' The leaders described varied approaches—ranging from sustained thematic contexts to brief introductory hooks—showing how empathy may engage diverse learners. These practical examples illustrate Baron-Cohen et al.'s (2005) Empathizing-Systemizing theory in educational settings. More specifically, the observation by leaders that empathy pedagogy has particular relevance for biology and health-related contexts affirms Zeyer and Dillon's (2019) findings about disciplinary variations in empathy's motivational effects. The potential gender

implications noted by our leaders suggest important connections to persistent issues of gender representation in STEM fields—an area where empathy-based approaches may offer untapped potential for addressing disparities.

Empathy as an Aim: Humanist Orientations

Building on NOS debates introduced in the Introduction (e.g., Longino, 1990), our findings affirm that empathy as an aim rejects value-free science, aligning with contemporary NOS models that integrate values as essential (Ambrosj et al., 2022). Our findings on empathy as an educational aim both confirm and extend humanist perspectives in the literature. These interpretations trace directly to data, such as primary teachers' emphasis on value-based pedagogy (P3/P4 quotes) and cross-group frequencies showing humanist dominance (Table 2).

First, the leaders articulated empathy as a fundamental educational value from both theoretical and practical lenses. Theoretically, their arguments treating empathy as a fundamental educational principle align with global educational priorities identified by the OECD (2019) and echo Goleman's (1996) assertion about empathy's central role in character development. Our leaders further provided more specific justifications for empathy's importance in STEM contexts, particularly emphasizing its role in preventing harm—a dimension not fully explored in previous literature.

Practically, the leaders' emphasis on explicit guidance for value-based especially empathy-centered teaching represents an important departure from the "neutral chair" approach traditionally advocated in science education (Oulton et al., 2004). Their perspectives align with more recent pedagogical frameworks (Frydaki, 2009; Maxwell, 2023) that acknowledge the impossibility of value-neutral instruction and the need for transparency in value positions. This suggests an important shift in how value education is viewed within STEM domains.

Second, the debate among our leaders regarding empathy's role in defining STEM's boundaries offers new insights into ongoing discussions about disciplinary integration. The critique of "value-free" STEM education as "cold" or "over-technical" from our leaders echoes concerns raised by scholars about the illusory objectivity of STEM (Donovan et al., 2021; Visintainer, 2022). Our findings reflect the persistence of legacy views regarding value-free science among some leaders, illustrating the ongoing influence of these historical debates. Simultaneously, our leaders' concerns about disciplinary dilution provide important counterpoints to the uncritical expansion of STEM into STEAM or other permutations—concerns that have received less attention in the literature promoting interdisciplinary approaches. These legitimate concerns about disciplinary integrity must be addressed in thoughtful and collective movements.

Third, regarding empathy as an ultimate goal, the positioning of empathy as a catalyst for social service aligns with Ortiz-Revilla et al.'s (2020) vision of STEM education as pursuing social justice through comprehensive technoscientific literacy. Furthermore, our leaders' view of empathy as a defining outcome—rather than just a process—represents a more radical shift in the purpose of STEM education than is typically found in existing literature. This challenges conventional metrics of STEM success and suggests the need for broader outcome measures that capture empathetic development.

Reconciling Perspectives: Beyond Binary Frameworks

Most strikingly, our findings touch on and additionally challenge the binary opposition often implied between utilitarian and humanist orientations in STEM education literature. Empathy's potential disregard is not engineering-specific but a broader STEM challenge, as evidenced by NOS debates across disciplines where value integration remains contested (Erduran, 2023). For example, McComas and Burgin's (2020) critique of undiscriminating STEM expansion finds support in our leaders' concerns, while Zeyer and Dillon's (2019) call for caution in empathy

integration resonates with warnings about potential disciplinary dilution.

Indeed, these two orientations of STEM education do not inherently exclude each other. The U.S. National Curriculum Document's three goals of STEM education (National Research Council, 2013)—developing innovators, strengthening the workforce, and improving citizen literacy—represent both orientations, suggesting compatibility rather than conflict. The theoretical model proposed by Walther et al. (2017) offers a promising framework for reconciling these perspectives through its three dimensions: skill, orientation, and professional way of being. Although Walther et al.'s model originates in engineering, it generalizes to STEM broadly, as empathy similarly bridges technical skills in fields like biology (e.g., empathetic bioethics) and physics (e.g., community-impact assessments), ensuring a comprehensive theoretical approach. Our findings provide empirical support for this model while highlighting the need to emphasize the "being" dimension that connects utilitarian skills to humanistic values. Similarly, our leaders' perspectives on design thinking reveal both the widespread focus on "how" questions and the untapped potential of the "who" and "why" dimensions that could more fully integrate humanistic concerns.

We argue that frameworks such as Design Thinking, PBL, SSI, and STEAM offer promising approaches to reconciliation. Design thinking, for example, reconciles the dichotomy by positioning empathy as both a tool (utilitarian, e.g., problem identification) and an aim (humanist, e.g., human flourishing). This is supported by findings where leaders unprompted linked empathy to design processes (e.g., S2, O1 quotes). Similarly, SSI reconciles via societal empathy (Trott et al., 2023), STEAM via artistic (Bush et al., 2024), and PBL via applied/theoretical integration (Maiorca et al., 2021). These frameworks are echoed in the results' humanist dominance (19 references) balanced with utilitarian consensus (8 references), showing their promise for navigating tensions like boundary concerns. This synthesis illustrates empathy's

role across STEM implementations for diverse outcomes—social justice, product innovation, and artistic integration. Our findings support empathy's integration across aspects: leaders' emphasis on problem-solving (utilitarian) aligns with applied engineering, while humanist aims extend to theoretical math through PBL, where empathy motivates ethical applications (e.g., S2 and P1 quotes on serving society).

More fundamentally, the tensions revealed in our study reflect deeper questions about the defining characteristic of STEM education that are not fully addressed in current literature: should empathy be integrated into the very definition of what constitutes STEM education, or should it remain external to STEM's definitional boundaries?

Indeed, empathy has been argued as a value system in action that embraces the inherent humanism and social embeddedness of STEM practices both in-school and out-of-school (Walther et al., 2017). Thus, STEM learning should recognize how STEM is practiced in society rather than in abstract terms (Conlon & Zandvoort, 2011; Trevelyan, 2010). This stems from the compelling evidence that STEM design processes and their products are particularly context-specific, far distinguished from the scientific knowledge, which may be barely deemed as somehow context-general (Antink-Meyer & Brown, 2019). This context-specific feature also applies to empathy learning and application (Stellar & Duong, 2023; Wieck et al., 2022). Educators and scholars in multicultural and educational philosophy collectively observe that students often encounter resistance when engaging with the emotional dimensions of learning, such as empathy. Even intentionally developed empathy can be fleeting, disappearing shortly after away from the particular educational environment, let alone the expected transfer in other contexts (Jackson, 2014a). Given the shared context-specific feature of empathy and STEM activities, we cannot expect our students to act in a humanist-oriented manner without being educated empathetically in specific STEM contexts, which underscores the need for authentic

integration of empathy within STEM contexts rather than treating it as a separate educational domain.

In sum, our leaders' perspectives suggest that the literature on empathy's role in STEM education requires more nuanced frameworks that move beyond binary oppositions between utilitarian and humanistic orientations. The shared context-specific feature of empathy and STEM practices further requires an authentic integration beyond debating within such binary frameworks.

Implications for STEM Education Reform

Local Curriculum Development in Hong Kong

Our findings imply that empathy integration should not be limited to specific topics like SSI; instead, it can guide topic selection broadly, as seen in design thinking or PBL for technical challenges or SSI for societal ones, ensuring empathy enhances STEM without rigid criteria.

The current state of STEM education in Hong Kong provides a critical context for interpreting these findings. In this hybrid context blending Eastern pro-social values and Western integrative approaches, tensions manifest between exam-driven technical focus and emerging value integration (Fensham, 2008). HK STEM programs increasingly incorporate societal factors, such as Sustainable Development Goals (SDGs) and social innovation, often implemented through competitions. While these initiatives have enhanced student engagement (Geng et al., 2019), the average practice often defaults to a 'tool-first' and solutionism approach. Many programs prioritize technical feasibility, product polish, and pitching performance over cultivating deep empathy with the situation (Ma & Chung, 2020). This tendency is particularly evident when schools outsource STEM programs to external providers, often due to teachers' low self-efficacy and curriculum overload. In such contexts, external institutions face implicit pressure to showcase the presentability of students' work as a means of securing contract renewal from

schools.

Interestingly, the criteria for winners in STEM competitions often vary by age cohort. In some city-wide competitions (take the City I&T Grand Challenge Hong Kong for example), primary and secondary groups explicitly include empathy under dimensions like 'Impacts and benefits to target end users' (e.g., 30%) and 'Understanding the user's pain points' (e.g., additional 30%). However, at the university level, these criteria are often de-emphasized, favoring technical feasibility, with 'community impact' weighted less (e.g., 25% vs a sum of 60% at K-12 level). Furthermore, some school-level competitions emphasize innovation and technical difficulty without explicitly mentioning empathy or problem understanding. This pattern strikingly corroborates our findings: primary and secondary teachers strongly emphasized empathy as an aim, while university professors expressed concerns about disciplinary dilution.

This tendency toward solutionism, prioritizing 'how' over 'who' and 'why,' is not unique to Hong Kong but is common in international STEM events. Regionally, South Korea has recently begun critically evaluating the pitfalls of a tool-centered approach in AI education following stakeholder backlash (Jeong, 2024)—a public discussion not yet prominent in Hong Kong.

Our findings call for concrete actions in Hong Kong's STEM curriculum development to address these limitations by supporting humanist integration.

First, empathy-based design thinking and PBL should be explicitly incorporated into curriculum guidelines rather than leaving them implicit. The leaders' strong endorsement of empathy as both a tool and aim aligns perfectly with Hong Kong's forthcoming science curriculum framework that emphasizes socio-scientific issues (Curriculum Development Council, 2024a). The leaders specifically endorsed empathy's "tool" function, confirming that empathy serves as a teachable core skill that improves problem-solving outcomes (Walther et al., 2017). When empathy

becomes explicit, students develop greater creative confidence and pro-social tendencies (Kijima et al., 2021). Concretely, we recommend mandating empathy rubrics in curricula (e.g., allocating weighting in projects for user pain points, as seen in some competitions) to counter solutionism, and revising instruction to start units with empathy exercises (e.g., stakeholder interviews), supported by leaders' consensus on procedural value.

Second, Hong Kong should develop a balanced approach that maintains STEM's disciplinary rigor while expanding its relevance through empathy. Findings suggest aligning empathy with STEAM/STREAM in Hong Kong curricula, e.g., adding artistic expressions to PBL for emotional empathy, prioritizing 'who' and 'why' alongside 'how'. This balanced approach addresses university leaders' concerns about dilution—concerns also evident in the analysis of university-level competition criteria—while respecting school educators' emphasis on empathy as an educational value. Integrating empathy directly into problem-solving enhances creativity and solution relevance without compromising technical rigor (McCurdy et al., 2020).

Third, our findings highlight a critical need to address the misalignment between K-12 and higher education regarding empathy's role in STEM. While primary and secondary educators strongly emphasize empathy, the resistance from some university faculty—corroborated by the de-emphasis of empathy in university-level competition criteria—poses a significant risk. University education is the "last mile" connecting education to careers; marginalizing empathy at this stage risks forfeiting prior K-12 efforts, just as projects approach real societal impact. Furthermore, university faculty in Hong Kong are highly influential in K-12 professional development and policy. Therefore, aligning educators across all developmental sequences is crucial. Concretely, we recommend (1) initiating structured dialogues between university STEM faculties and K-12 leaders to bridge the gap regarding disciplinary boundaries and humanistic aims, and (2) revising university STEM curricula and assessment criteria (including

competitions) to explicitly integrate empathy, ensuring continuity and amplifying the value of empathy throughout the educational pipeline.

Toward Culturally Responsive STEM Pedagogies

The diverse perspectives within our single Hong Kong study highlight how empathy integration is shaped by institutional structures and cultural contexts. Educational systems worldwide must consider how their existing curricular arrangements either facilitate or hinder empathy's integration into STEM education. Students with stronger empathy and "soft skills" hold more positive attitudes toward interdisciplinary curriculum integration, suggesting that social-emotional factors can support STEM educational reforms (Hwang, 2022). The effectiveness of empathy-centered approaches depends largely on whether educational systems compartmentalize values education or integrate it across disciplines.

Different curricular structures worldwide offer contrasting approaches to integrating empathy in STEM education. Some educational systems organize learning around real-world phenomena rather than discrete subjects, creating natural spaces for empathy within STEM contexts. Others maintain rigid disciplinary boundaries that make empathy integration more challenging. These structural differences highlight that empathy integration strategies must be responsive to existing educational traditions rather than imposed as universal solutions.

Recent evidence strengthens the case for thoughtful empathy integration. In Hong Kong STEM programs incorporating community service learning, students' empathy positively influences their desire for community involvement, which in turn enhances their perseverance in STEM learning (Nalipay et al., 2024). This reveals a powerful synergy: when STEM education connects technical knowledge with human needs through empathy, students find greater meaning and motivation in their learning. Educational systems that create these connections through

community-oriented projects provide students with more avenues to experience STEM as socially relevant and personally meaningful.

The tension in our findings between empathy as an essential STEM element versus a potential distraction echoes broader international questions about disciplinary boundaries. Rather than prescribing universal approaches, curriculum developers should assess how their specific contexts might integrate empathy while respecting both disciplinary integrity and broader educational values. STEM education increasingly focuses on developing "humanistic knowledge" and the ability to "listen with understanding and empathy," representing a global shift toward more socially conscious approaches (Teo et al., 2024). Educational innovators can adapt these trends thoughtfully, creating contextually sensitive approaches that align with local priorities while fostering meaningful connections between empathy and STEM learning.

International Implications

Our findings offer valuable contributions to international discourse on empathy's role in STEM education, particularly regarding the tension between utilitarian and humanistic orientations. Rather than reinforcing this binary opposition, our leaders reveal a more nuanced reality where empathy functions simultaneously as both a tool and an aim. This integrated perspective can inform curriculum development internationally, balancing disciplinary rigor with humanistic concerns in ways that enrich rather than dilute STEM education. Recent conceptual frameworks for STEM curricula now embed empathic design principles to address multicultural and ethical considerations alongside technical skills (Shim, 2024).

The university leaders' cautions about empathy potentially diluting STEM's disciplinary focus serve as important counterpoints to uncritical expansion trends internationally. As educational systems explore STEAM and STREAM variations, our findings highlight the importance of

maintaining disciplinary clarity while thoughtfully incorporating humanistic elements. Empathy integration need not sacrifice scientific rigor; when properly implemented, it can enhance innovation by connecting problem-solving to ethical reflection and societal needs. Students who perceive STEM fields as avenues to others and contribute to society show greater persistence and excellence—illustrating that empathy can strengthen rather than weaken STEM outcomes (Fuesting & Diekman, 2017). Balancing these priorities is key to developing STEM education policies that are both forward-thinking and context-sensitive ().

The correlation between leaders' perspectives and their professional roles has significant implications for international policy development. University researchers, primary and secondary educators, and out-of-school STEM education providers each contributed distinct perspectives in our study. This finding suggests that STEM education policy initiatives would benefit from deliberately incorporating diverse stakeholders rather than privileging academic or practitioner voices alone. The richest approaches to empathy integration emerge when multiple professional perspectives inform policy development (Chen, Sonnert & Sadler, 2020).

Building Consensus Through Dialogue

The lack of consensus among our leaders regarding empathy as an aim reveals both challenges and opportunities. While school-based educators and two university leaders strongly endorsed empathy as an educational aim, three university faculties and two out-of-school STEM education providers objected to this function. This division calls for increased professional dialogue that explicitly addresses how structural and contextual factors shape empathy's role in STEM education.

We advocate a two-way perspective shift: leaders who voiced objections to empathy as an aim should consider the comprehensive justifications from school-based educators who witness its

benefits firsthand, while those advocating for empathy as an aim should acknowledge the critical reminder about an extreme "pure" humanist orientation potentially blurring STEM's nature and boundaries. This balanced approach is particularly important in navigating between traditional emphases on academic achievement and increasing recognition of broader educational aims.

The most promising path forward combines both "aim" and "tool" functions, carefully calibrating empathy's role to serve both instrumental and humanistic purposes without compromising either. This approach recognizes that empathy's integration into STEM education reflects fundamental values about education's purpose in society—values that should be explicitly discussed rather than implicitly assumed.

Limitations and Future Work

Several limitations warrant acknowledgement and suggest directions for future research.

While the sample size of leaders, particularly those interviewed in-depth, is relatively limited, it is important to note that our participants represent a rare assembly of leading STEM education leaders in Hong Kong, an international hub with significant influence in global discourse. These participants include key policy advisors, curriculum developers, and educational leaders whose perspectives directly shape educational reforms and implementation at both system and classroom levels. The scarcity of such high-level leaders in any educational system means that even a relatively small sample captures a significant proportion of those who most influence STEM education policy and practice in this context. Their insights therefore carry substantial weight in understanding how empathy is viewed at the highest levels of educational planning and implementation.

Nevertheless, although we identified associations between leaders' views and their professional roles, the patterns described should be considered preliminary rather than conclusive. A larger

sample across each professional category would enable more robust comparisons and potentially reveal more nuanced patterns in how different stakeholders view empathy's role in STEM education.

Our study is also limited to the Hong Kong context, which has its own distinctive educational traditions and policy landscape. Participants' perspectives may reflect specific aspects of Hong Kong's educational system, including its examination culture, curriculum structure, and ongoing educational reforms. Without comparative data from other cultural and educational contexts, we cannot determine which aspects of our findings reflect universal perspectives on empathy's role in STEM education versus those that may be specific to Hong Kong. International comparative studies would be necessary to disentangle these factors.

Third, our study relied on leader opinions rather than direct classroom observations or student outcomes. While leader perspectives provide valuable insights into policy intentions and educational philosophies, they may not fully capture how empathy is actually implemented in STEM classrooms or experienced by students. Future research should complement leader interviews with classroom observations, teacher practice studies, and student-centered research to develop a more comprehensive understanding of empathy's role in STEM education.

Fourth, our interview protocol, while comprehensive, may have prompted certain types of responses or framed discussions in particular ways. The questions we asked and how we asked them inevitably shaped the data collected. Different methodological approaches, such as ethnographic studies, longitudinal observations, or experimental designs, might reveal additional dimensions of how empathy functions in STEM education that were not captured in our interview-based approach.

Finally, our study did not specifically explore potential developmental differences in how

empathy might be integrated into STEM education across different age groups. The finding that primary school educators particularly emphasized value-based pedagogy suggests that different approaches might be appropriate at different educational levels, but our study was not designed to systematically investigate this possibility. Future research should examine how empathy-based approaches to STEM education might be developmentally sequenced from primary through secondary education.

Nevertheless, we believe that the insights gathered from these influential leaders may be vivid miniatures of how STEM education leaders, both locally and globally, see empathy in current and future images of STEM education reform. It is evident that a more cohesive collective sense-making of this issue is still evolving. In this regard, we encourage more professional dialogue and empirical studies, particularly from the lens of international comparison among diverse STEM education stakeholders in Hong Kong and across various regions. Such research could examine how cultural contexts, educational systems, and professional roles interact to shape views of empathy's role in STEM education. Additionally, intervention studies testing different approaches to integrating empathy into STEM education could provide valuable evidence regarding effective practices and student outcomes.

Conclusion

This study advances our understanding of empathy's role in STEM education by examining how diverse leaders conceptualize its purpose and implementation. Through our new analytical framework of utilitarian and humanist orientations, we revealed complex patterns in how educational leaders position empathy within STEM education. This framework enabled us to identify that STEM education leaders predominantly embrace a humanist perspective. These leaders position empathy as both a tool for effective learning and an educational aim in itself.

This reflects a significant shift in STEM education philosophy both locally and globally.

Our research makes three key contributions to the field. Theoretically, our two-fold orientation framework provides a structured lens for analyzing the role of empathy (and potentially other values/concepts) in STEM education. We further suggested reconciling perspectives that move beyond binary oppositions. Empirically, we documented how professional roles significantly influenced leaders' views, with school-based educators emphasizing empathy's value as an educational aim while university faculty expressed greater concern about maintaining disciplinary boundaries. Practically, we identified specific tensions around disciplinary boundaries while revealing consensus regarding empathy's instrumental value in design processes.

The tension between empathy as an essential element of STEM education versus a potential distraction from disciplinary focus reflects deeper questions about STEM's purpose in society and the defining characteristics of STEM education. Our findings suggest that effective empathy integration requires balancing these perspectives through approaches that explicitly incorporate empathy within design thinking, PBL, SSI, and STEAM while maintaining disciplinary rigor, with different emphases across educational levels.

Moving forward, STEM education policy development would benefit from the deliberate inclusion of diverse stakeholders in professional dialogue about empathy's role. This approach would help create context-sensitive integration strategies that honor both the technical foundations and humanistic aspirations of contemporary STEM education (Wilson & Mukhopadhyaya, 2022).

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The authors declare that they have no competing interests.

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References

Abd-El-Khalick, F., Myers, J. Y., Summers, R., Brunner, J., Waight, N., Wahbeh, N., Zeineddin, A. A., & Belarmino, J. (2017). A longitudinal analysis of the extent and manner of representations of nature of science in U.S. high school biology and physics textbooks. *Journal of Research in Science Teaching*, *54*(1), 82–120.

Almers, E. (2013). Pathways to action competence for sustainability—Six themes. *The Journal of Environmental Education*, *44*(2), 116-127.

Ambrosj, J., Dierickx, K., & Desmond, H. (2022). The value-free ideal of science: a useful fiction? A review of non-epistemic reasons for the research integrity community. *Medicina Historica*, *6*(2), 69-69.

Ampuero, D., Miranda, C. E., Delgado, L. E., Goyen, S., & Weaver, S. (2015). Empathy and critical thinking: Primary students solving local environmental problems through outdoor learning. *Journal of Adventure Education & Outdoor Learning*, *15*(1), 64-78.

Antink-Meyer, A., & Brown, R. A. (2019). Nature of engineering knowledge: An articulation for science learners with nature of science understandings. *Science & Education*, *28*(3), 539-559.

Baron-Cohen, S., Knickmeyer, R. C., & Belmonte, M. K. (2005). Sex differences in the brain: implications for explaining autism. *Science*, *310*(5749), 819-823.

Boss, S., & Krauss, J. (2018). *Reinventing project based learning: Your field guide to real-world projects in the digital age*. ASCD.

Bush, S. B., Cook, K. L., Edelen, D., & Cox Jr, R. (2020). Elementary students' STEAM perceptions: Extending frames of reference through transformative learning experiences. *The Elementary School Journal*, *120*(4), 692-714.

Bush, S. B., Edelen, D., Roberts, T., Maiorca, C., Ivy, J. T., Cook, K. L., Tripp, L. O., Burton, M., Alameh, S., & Jackson, C. (2024). Humanistic STE (A) M instruction through empathy: leveraging design thinking to improve society. *Pedagogies: An International Journal, 19*(1), 60-79.

Castano, C. (2008). Socio-scientific discussions as a way to improve the comprehension of science and the understanding of the interrelation between species and the environment. *Research in Science Education*, *38*(5), 565-587.

Chen, C., Chen, S., Haste, H., Selman, R. L., & Schneps, M. H. (2023). Romantic Transfer from Thermodynamic Theories to Personal Theories of Social Control: A Randomised Controlled Experiment. *Education Sciences*, *13*(6), 599.

Chen, C., Chen, J., Ju, L., Sonnert, G., Sunbury, S., & Sadler, P. (2024). Kitchen Chemistry Boosts STEM Identity and Increases STEM Career Interests. *Journal of Chemical Education*. https://doi.org/10.1021/acs.jchemed.3c01141

Chen, C., & Sonnert, G. (2024). Ideals of the good life and good science among high achieving men and women scientists. *SN Social Sciences*, *4*(2), 1-20.

Chen, C., Sonnert, G. & Sadler P. (2021). What a Difference a Decade makes: The Gender Gap in Students' Career Related Goal Endorsement, From 2007 to 2017. *Journal of Social Change. 12(1),* 14. https://doi.org/10.5590/JOSC.2020.1.1.14

Chesky, N. Z., & Wolfmeyer, M. R. (2015). *Philosophy of STEM education: A critical investigation*. Springer.

Cheung, K. K. C. (2020). Exploring the inclusion of nature of science in biology curriculum and high-stakes assessments in Hong Kong: Epistemic network analysis. *Science & Education*, *29*(3), 491-512.

Conlon, E., & Zandvoort, H. (2011). Broadening ethics teaching in engineering: Beyond the individualistic approach. *Science and Engineering Ethics*, *17*(2), 217-232.

Cooper, B. (2011). *Empathy in education: Engagement, values and achievement*. Bloomsbury Publishing.

Curriculum Development Council. (2017). General Studies Curriculum Guide for Primary School. https://www.edb.gov.hk/attachment/en/curriculum-development/cross-kla-studies/gs-primary/GSCG_2017_Eng.pdf.

Curriculum Development Council. (2024a). Science (Secondary 1-3) curriculum framework (Consultation draft). https://www.edb.gov.hk/attachment/en/curriculum-development/kla/science-edu/jss/Science_(S1-

3)_Curriculum_Framework_Consultation_Draft_en.pdf

Curriculum Development Council. (2024b). Science (Primary 1-6) curriculum framework (Final Version). https://www.edb.gov.hk/attachment/en/curriculum-development/kla/science-edu/pri-sci/Pri_Sci_Curriculum_Framework_Eng.pdf

Curriculum Development Council. (2024c). Citizenship, Economics and Society Curriculum Guide (Secondary 1-3). https://www.edb.gov.hk/attachment/en/curriculum-development/kla/pshe/CESCG_e_20240730%20clean.pdf

Decety, J., & Cowell, J. M. (2014). Friends or foes: Is empathy necessary for moral behavior?. *Perspectives on Psychological Science*, *9*(5), 525-537.

Donovan, B. M. (2017). Learned inequality: Racial labels in the biology curriculum can affect the development of racial prejudice. *Journal of Research in Science Teaching*, *54*(3), 379-411.

Donovan, B. M., Weindling, M., & Lee, D. M. (2020). From basic to humane genomics literacy: how different types of genetics curricula could influence anti-essentialist understandings of race. *Science & Education*, *29*(6), 1479-1511.

Donovan, B. M., Weindling, M., Salazar, B., Duncan, A., Stuhlsatz, M., & Keck, P. (2021). Genomics literacy matters: Supporting the development of genomics literacy through genetics education could reduce the prevalence of genetic essentialism. *Journal of Research in Science Teaching*, *58*(4), 520-550.

Dvash, J., & Shamay-Tsoory, S. G. (2014). Theory of mind and empathy as multidimensional constructs: Neurological foundations. *Topics in Language Disorders*, *34*(4), 282-295.

Edelen, D., Cook, K., Tripp, L. O., Jackson, C., Bush, S. B., Mohr-Schroeder, M. J., ... & Perrin, A. (2024). “No, This Is Not My Boyfriend’s Computer”: Elevating the Voices of Youth

in STEM Education Research Leveraging Photo-Elicitation. *Journal for STEM Education Research*, *7*(3), 444-462.

Eisenberg, N. (2000). Emotion, regulation, and moral development. *Annual review of psychology*, *51*(1), 665-697.

Erduran, S. (2023). Social and institutional dimensions of science: The forgotten components of the science curriculum?. *Science*, *381*(6659), eadk1509.

Erduran, S., & Dagher, Z. R. (2014). Reconceptualizing nature of science for science education. In *Reconceptualizing the nature of science for science education: Scientific knowledge, practices and other family categories* (pp. 1-18). Dordrecht: Springer Netherlands.

Fensham, P. (2008). *Science education policy-making* (p. 47). Paris: uNescO.

Frydaki, E. (2009). Values in teaching and teaching values: A review of theory and research, including the case of Greece. *Mediterranean Journal of Educational Studies, 14* (1), 109–128.

Fuesting, M. A., & Diekman, A. B. (2017). Not by success alone: Role models provide pathways to communal opportunities in STEM. *Personality and Social Psychology Bulletin*, *43*(2), 163-176.

Garibay, J. C. (2015). STEM students' social agency and views on working for social change: Are STEM disciplines developing socially and civically responsible students?. *Journal of Research in Science Teaching*, *52*(5), 610-632.

Garibay, J. C. (2018). Beyond traditional measures of STEM success: Long-term predictors of social agency and conducting research for social change. *Research in Higher Education*, *59*(3), 349-381.

Garner, P. W., Gabitova, N., Gupta, A., & Wood, T. (2018). Innovations in science education: Infusing social emotional principles into early STEM learning. *Cultural Studies of Science Education*, *13*(4), 889-903.

Geng, J., Jong, M. S. Y., & Chai, C. S. (2019). Hong Kong teachers' self-efficacy and concerns about STEM education. *The Asia-Pacific Education Researcher*, *28*(1), 35-45.

Goleman, D. (1996). Emotional intelligence. Why it can matter more than IQ. *Learning*, *24*(6), 49-50.

Gough, A. (2015). STEM policy and science education: Scientistic curriculum and sociopolitical silences. *Cultural Studies of Science Education*, *10*(2), 445-458.

Guney, B. G., & Seker, H. (2012). The Use of History of Science as a Cultural Tool to Promote Students' Empathy with the Culture of Science. *Educational Sciences: Theory and Practice*, *12*(1), 533-539.

Han, Z., & Wei, B. (2024). When Nature of Science Meets Quantum Physics: Insights from NOS Representation in Chinese Physics Textbooks. *Science & Education*, *34*(5), 3269–3289.

Henriksen, D., Richardson, C., & Mehta, R. (2017). Design thinking: A creative approach to educational problems of practice. *Thinking skills and Creativity*, *26*, 140-153.

Hodge, B. (1999). The Sokal 'Hoax': some implications for science and postmodernism. *Continuum: Journal of Media & Cultural Studies*, *13*(2), 255-269.

Holmlund, T. D., Lesseig, K., & Slavit, D. (2018). Making sense of "STEM education" in K-12 contexts. *International journal of STEM education*, *5*(1), 32.

Hwang, S. (2022). Effects of engineering students' soft skills and empathy on their attitudes toward curricula integration. *Education Sciences*, *12*(7), 452.

Jackson, C., Mohr-Schroeder, M. J., Bush, S. B., Maiorca, C., Roberts, T., Yost, C., & Fowler, A. (2021). Equity-oriented conceptual framework for K-12 STEM literacy. *International Journal of STEM Education*, *8*(1), 38.

Jackson, L. (2014a). Altruism, non-relational care, and global citizenship education. *Philosophy of Education*, *70*, 409–417.

Jackson, L. (2014b). 'Won't Somebody Think of the Children?'Emotions, child poverty, and post-humanitarian possibilities for social justice education. *Educational Philosophy and Theory*, *46*(9), 1069-1081.

Jeong, H.-S. (2024, December). AI digital technologies and school education [AI 디지털 기술과 학교 교육]. *Seoul Education Webzine.* Seoul Educational Research & Information Institute, Seoul Metropolitan Office of Education. https://webzine.serii.re.kr/ai-%eb%94%94%ec%a7%80%ed%84%b8-%ea%b8%b0%ec%88%a0%ea%b3%bc-%ed%95%99%ea%b5%90-%ea%b5%90%ec%9c%a1/

Kant, I. (1785). Groundwork of the Metaphysics of Morals (1785). *New Haven*.

Kelley, T. (2001). *The art of innovation: Lessons in creativity from IDEO, America's leading design firm* (Vol. 10). Crown Currency.

Kijima, R., Yang-Yoshihara, M., & Maekawa, M. S. (2021). Using design thinking to cultivate the next generation of female STEAM thinkers. *International Journal of STEM Education*, *8*(1), 14.

Kokotsaki, D., Menzies, V., & Wiggins, A. (2016). Project-based learning: A review of the literature. *Improving schools*, *19*(3), 267-277.

Lacey, H. (2005). *Is science value free?: Values and scientific understanding*. Routledge.

Lamb, R., Akmal, T., & Petrie, K. (2015). Development of a cognition-priming model describing learning in a STEM classroom. *Journal of Research in Science Teaching*, *52*(3), 410-437.

Lederman, N. G. (2013). Nature of science: Past, present, and future. In *Handbook of research on science education* (pp. 831-879). Routledge.

Letizia, A. J. (2016). STEM and democracy. In *Democracy and social justice education in the information age* (pp. 79-95). Cham: Springer International Publishing.

Li, X., Chen, J., & Fu, H. (2024). The roles of empathy and motivation in creativity in design thinking. *International Journal of Technology and Design Education*, *34*(4), 1305-1324.

Liu, W., Huang, R., Wang, J., Chen, Y., Ohashi, T., Li, B., Liu, Y., Qiu, D., Yu, R., Zhang, J., Mahmud, A. A., & Leifer, L. (2024). Empathy Design Thinking: cultivating creative minds in primary education. *Frontiers in Education*, *9, 1376305*.

Longino, H. (1983). Beyond "bad science": Skeptical reflections on the value-freedom of scientific inquiry. *Science, Technology, & Human Values*, *8*(1), 7-17.

Longino, H. E. (1990). Science as social knowledge: Values and objectivity in scientific inquiry. Princeton University Press.

Ma, C. F. H., & Chung, K. Y. (2024). The Implication of the "Maker" Concept in STEM education in Hong Kong. In *International Symposium on Education and Social Sciences* (pp. 95-101).

Maiorca, C., Roberts, T., Jackson, C., Bush, S., Delaney, A., Mohr-Schroeder, M. J., & Soledad, S. Y. (2021). Informal learning environments and impact on interest in STEM careers. *International Journal of Science and Mathematics Education*, *19*(1), 45-64.

Makal, N., & Çepni, S. (2024). Increasing Students' Empathy Levels in Science Education: A Thematic Review. *Journal of Baltic Science Education*, *23*(5), 914-930.

Maxwell, B. (2023). Teacher Neutrality, Pedagogical Impartiality and Democratic Education. *The Cambridge Handbook of Democratic Education*, 607-627.

McComas, W. F., & Burgin, S. R. (2020). A critique of "STEM" education: Revolution-in-the-making, passing fad, or instructional imperative?. *Science & Education*, *29*(4), 805-829.

McCurdy, R. P., Nickels, M. L., & Bush, S. B. (2020). Problem-based design thinking tasks: Engaging student empathy in STEM. *The electronic journal for research in science & mathematics education*, *24*(2), 22-55.

McHugh, M. L. (2012). Interrater reliability: the kappa statistic. *Biochemia medica*, *22*(3), 276-282.

Mirhosseini, S. A. (2020). Data analysis through coding. In *Doing qualitative research in language education* (pp. 131-155). Cham: Springer International Publishing.

Nalipay, M. J. N., Huang, B., Jong, M. S., Chai, C. S., & King, R. B. (2024). Promoting STEM learning perseverance through recognizing communal goals: Understanding the impact of empathy and citizenship. *International Journal of STEM Education*, *11*(1), 17.

Narvaez, D. (2010). The emotional foundations of high moral intelligence. *New directions for child and adolescent development*, *2010*(129), 77-94.

National Research Council. (2013). *Monitoring progress toward successful K-12 STEM education: A nation advancing?*. National Academies Press.

OECD. (2019). Conceptual learning framework Learning Compass 2030. https://www.oecd.org/content/dam/oecd/en/about/projects/edu/education-2040/concept-notes/OECD_Learning_Compass_2030_concept_note.pdf

Ortiz-Revilla, J., Adúriz-Bravo, A., & Greca, I. M. (2020). A framework for epistemological

discussion on integrated STEM education. *Science & Education*, *29*(4), 857-880.

Oulton, C., Dillon, J., & Grace, M. M. (2004). Reconceptualizing the teaching of controversial issues. *International Journal of Science Education*, *26*(4), 411-423.

Portal, C. (1983). Empathy as an aim for curriculum: Lessons from history. *Journal of Curriculum studies*, *15*(3), 303-310.

Porter, L., Rickards, L., Verlie, B., Bosomworth, K., Moloney, S., Lay, B., Latham, B., Anguelovski, I., & Pellow, D. (2020). Climate justice in a climate changed world. *Planning Theory & Practice, 21*(2), 293-321.

Proctor, R. (1991). *Value-free science?: Purity and power in modern knowledge*. Harvard University Press.

Schaffar, B., & Wolff, L. A. (2024). Phenomenon-based learning in Finland: a critical overview of its historical and philosophical roots. *Cogent Education*, *11*(1), 2309733.

Schiepe-Tiska, A., Heinle, A., Dümig, P., Reinhold, F., & Reiss, K. (2021b). Achieving Multidimensional Educational Goals through Standard-Oriented Teaching: An application to STEM education. *Frontiers in Education*, *6*, 592165.

Schiff, D. S., Lee, J., Borenstein, J., & Zegura, E. (2025). Influences and inhibitors in STEM undergraduate social responsibility development. *International Journal of STEM Education*, *12*(1), 34.

Schlosberg, D., & Collins, L. B. (2014). From environmental to climate justice: climate change and the discourse of environmental justice. *Wiley Interdisciplinary Reviews: Climate Change*, *5*(3), 359-374.

Shim, S. W. (2024). Cultivating Empathy in STEM: A Conceptual Framework for Multicultural Empathic Design in STEM Education. *Journal of STEM Teacher Education*, *59*(1), 2.

Sokal, A. (2010). *Beyond the hoax: Science, philosophy and culture*. OUP Oxford.

Stellar, J. E., & Duong, F. (2023). The little black box: Contextualizing empathy. *Current Directions in Psychological Science*, *32*(2), 111-117.

Sun, K. L. (2017). Commentary: The Importance of Cultivating Empathy in Stem. *Science Scope*, *40*(8), 6-8.

Tagg, N., & Jafry, T. (2018). Engaging young children with climate change and climate justice. *Research for all*, *2*(1), 34-42.

Teo, T. W., Tan, A. L., & Choy, B. H. (2024). "It feels different when blindfolded": Developing social empathy through inclusive designs in STEM. *STEM Education, 4*(1), 20–34.

Trevelyan, J. (2010). Reconstructing engineering from practice. *Engineering Studies*, *2*(3), 175-195.

Trott, C. D., Lam, S., Roncker, J., Gray, E. S., Courtney, R. H., & Even, T. L. (2023). Justice in climate change education: A systematic review. *Environmental Education Research*, *29*(11), 1535-1572.

UNESCO, E. (2015). 2030–Incheon Declaration and Framework for Action. *Pars: UNESCO*.

Visintainer, T. (2022). Engaging the racist science of human intelligence: Towards a more just science education future. *Journal of Research in Science Teaching*, *59*(8), 1489-1492.

Waghid, Z. (2024). Cultivating critical thinking, social justice awareness and empathy among pre-service teachers through online discussions on global citizenship education. *Journal of Creative Communications*, *19*(1), 74-93.

Walther, J., Miller, S. E., & Sochacka, N. W. (2017). A model of empathy in engineering as a core skill, practice orientation, and professional way of being. *Journal of Engineering*

Education, *106*(1), 123-148.

Wieck, C., Scheibe, S., & Kunzmann, U. (2022). Development and validation of film stimuli to assess empathy in the work context. *Behavior Research Methods*, *54*(1), 75-93.

Wieder, W. (2006). Science as story: Communicating the nature of science through historical perspectives of science. *The American Biology Teacher*, 200-205.

Wilson, E., & Mukhopadhyaya, P. (2022). Role of empathy in engineering education and practice in North America. *Education Sciences*, *12*(6), 420.

Yao, C., Greenhoot, A. F., 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,* 1175871.

Yeung, W. L., & Ng, O. L. (2024). Using empathy maps to support design-thinking enhanced transdisciplinary STEM innovation in K-12 setting. *International Journal of Technology and Design Education*, *34*(4), 1325-1350.

Yoon, J., Jo, T. J., & Kang, S. J. (2020). A study on the possibility of the relationship among group creativity, empathy, and scientific inquiry ability of elementary school students. *International Journal of Science Education*, *42*(13), 2113-2125.

Zeyer, A. (2012). What is a potential scientist? Motivation to learn science—A question of culture or of cognition? In S. Markic, I. Eilks, D. D. Fuccia, & B. Ralle (Eds.), *Issues of heterogeneity and cultural diversity in science education and science education research* (pp. 53–58). Aachen: Shaker Verlag.

Zeyer, A. (2018). Gender, complexity, and science for all: Systemizing and its impact on motivation to learn science for different science subjects. *Journal of Research in Science Teaching*, *55*(2), 147-171.

Zeyer, A., & Dillon, J. (2019). The role of empathy for learning in complex Science| Environment| Health contexts. *International Journal of Science Education, 41*(3), 297-315.

Table 1 Coding scheme

Theme	Subtheme	Description	Quote (+)	Quote (-)
Tool	*Attention Drawing*	Empathy as a mechanism for capturing student attention, ranging from sustained contextual themes to brief introductory hooks	"Empathy is often important and manifested in health-related issues...My personal experience is that health-related issues are quite important. As our school is a girls' school, women students are all interested in these topics, such as medical care, biology, and health management." "If only pure STEM elements existed, it would be a bit bland and boring. If you use real estate tycoons as a starting point, students may gain more experience or understanding. I think providing students with a caring attitude for others, namely empathy, is completely right."	
	Problem Solving	Empathy as a procedural tool for effective problem solving in STEM design, particularly for addressing the "how" dimensions of design challenges	"I think empathy is very important; this is where they start to think about how to initiate STEM design and further serve society."	
Aim	*Educational Value*	Empathy as a fundamental educational principle and foundation for value-based pedagogy in STEM education	"Empathy must be at the highest level. The reason is that if you do not help people, then what are you doing? Isn't it?" "Without any guidance or with only a very loose description, teachers can only consider the design of these activities based on their values, maybe without empathy. This is dangerous because teachers have	

		different values or misunderstandings about certain things."	
Definitional Boundary	Empathy as either an essential expansion of what defines STEM education or a potential distraction from STEM's disciplinary clarity	"Students often tend to develop a specific technology product to help the old, but seldom really visit and accompany them. Without sincere caring for and empathy with others, STEM would be quite 'cold'."	"When we define the learning scope... we cannot extend STEM to an infinite extent and then call all the learning STEM."
Ultimate Goal	Empathy as either the catalyst for social service and defining outcome of STEM education or a possible distraction from STEM's core focus	"I think the focus of STEM education is to examine whether or not students can apply the interdisciplinary knowledge they have learnt to problem-solve, thereby optimizing their own lives as well as helping others. Namely, gradually from me to we, solve the problems shared by the society and world…empathy with others should play a role." "So we suppose this group benefited most from that event, not in the STEM techniques but in attitudes such as empathy."	"This is mainly not the teaching content of STEM Education... if you are saying that it is purely about caring for others or empathy, I do not think this is one of the most important attitudes of STEM education."

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Table 2 Views and Positions by Panel Groups

Theme	Subtheme	Position	University faculties	Secondary school teachers	Primary school teachers	Out-of-school education providers	Total frequency.	
Tool	Attention drawing	+		S1	P2		2	8
	Problem solving	+	U1	S2; S5	P1; P4	O1	6	
Aim	Educational value	+	U1; U5	S4	P3; P4		5	19
	Definitional boundary	+		S3	P3	O2	3	8
		-	U2; U3; U4			O1; O3	5	
	Ultimate goal	+		S1; S2	P1; P3	O2	5	6
		-	U4				1	

Table 3 Summary of Key Participant Views by Theme and Group (Tied to RQ1 and RQ2)

Theme/Subtheme	University	Secondary	Primary	Out-of-	Cross-Group

	Faculty (Examples)	Teachers (Examples)	Teachers (Examples)	School Providers (Examples)	Comparison (Tensions/Synergies)
Tool/Attention Drawing (+)	(Minimal mention)	S1: Health issues sustain interest	P2: Hooks for engagement	(None)	Synergy: School-based groups see motivational value; university minimal.
Tool/Problem Solving (+)	U1: Catalyst in design	S2/S5: Initiates STEM design	P1/P4: Drives specific designs	O1: Identifies problems	Consensus across all: Procedural utility in design.
Aim/Educational Value (+)	U1/U5: People-centered core	S4: Key principle	P3/P4: Highest priority, value-based pedagogy	(None)	Tension: Primary strongest emphasis; out-of-school absent.
Aim/Definitional Boundary (+)	(None)	S3: Expands boundaries	P3: Prevents 'cold' STEM	O2: Includes humanities	Synergy: School/out-of-school support expansion.
Aim/Definitional Boundary (-)	U2/U3/U4: Risks dilution	(None)	(None)	O1/O3: Broad, not main aim	Tension: University/out-of-school cautious vs. school support.
Aim/Ultimate Goal (+)	(None)	S1/S2: Catalyst for social service	P1/P3: Defining outcome	O2: Attitude change priority	Synergy: School/out-of-school emphasizes transformative goals.
Aim/Ultimate Goal (-)	U4: Not core focus	(None)	(None)	(None)	Tension: University reluctance vs. others' endorsement.

Note: Based on frequencies in Table 2 and quotes in results; addresses RQ1 (orientations) and RQ2 (group variations).