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Love and Its Attributes as a Foundation for Student Learning in Engineering Education

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Introduction

Engineering plays a critical role in shaping ecosystems, human behavior, communities, societies, and patterns of power through the design and deployment of structures, technologies, and complex systems. While contemporary corporate-driven Western engineering is often framed as solving problems and enhancing quality of life, the forces driving technological development—economic interests, techno-evolutionary pressures, political agendas, technological path dependencies, national security concerns, individual ambitions, and considerations of ethics and ecological sustainability—often conflict, ultimately undermining these aims. These systemic and psychological dynamics are frequently obscured in engineering discourse and education. Recognizing them is essential to understanding how individual mental states and behaviors both shape and are shaped by broader social, economic, and governance structures. Within this interplay, human capacities for love and compassion influence our priorities, inform how we define and frame problems, and guide our approaches to interpersonal relationships and engineering challenges—including those that extend beyond purely human interests.

As a result, engineering outcomes—contingent on period, context, and scale—can sometimes address immediate problems while deepening environmental and social challenges. This paradox is especially evident in contemporary, profit-driven models that prioritize technical and economic goals, often under the banner of human-centered design, while marginalizing ethical and relational concerns [1]–[6]. These models constrain inquiry by privileging narrow design logics over broader, holistic concerns—a narrowing that extends into engineering education, where students' engagement with the humanities, arts, and social sciences is limited, restricting more diverse perspectives.

Against this backdrop, love and its attributes—empathy, compassion, care, and action—are proposed as foundational to students' ethical engagement, learning, and design practices. This paper introduces a framework that places love at the heart of engineering education, challenging conventional paradigms and expanding the purpose and possibilities of engineering.

Historically, humans have engaged in design and toolmaking driven by diverse needs, values, and relationships. The emergence of love, empathy, compassion, and care likely contributed to the formation of social structures and early technologies, particularly during pivotal periods in human history beginning around 50000 years ago [7]. These values continue to inform the design ethics of many Indigenous cultures—from North America to the Brazilian Amazon to Australia—whose communities have long practiced sustainable living through technologies grounded in reciprocity, relationality, and respect for the natural world [8], [9].

While this paper focuses on Western engineering education in the United States (U.S.), it acknowledges these longstanding design traditions and recognizes U.S. engineering programs that incorporate humanitarian or human-centered approaches. Building on these diverse legacies, it suggests a shift away from capitalist design paradigms toward frameworks grounded in relational awareness and holistic responsibility.

This paper constructs a conceptual and applied framework for engineering education that begins with students' engagement in the study and practice of love. Drawing on holistic and transdisciplinary perspectives, which bridge students' technical abilities with neuroscientific, psychological, and socio-ecological knowledge, this paper explores how love is interwoven with empathy, compassion, and care—as well as with ethics, design, and technology—offering students a way of knowing and practicing engineering that moves beyond technological determinism and human-centered thinking. The framework is then applied in educational contexts to examine its implementation and effects.

Despite its potential, the teaching of love and its attributes remains largely absent from U.S. engineering curricula. The dominant emphasis on technical mastery often sidelines students' emotional and relational development, as well as their deeper understanding and engagement with the social, historical, and ethical contexts of technological development—limiting their capacity for ethical reasoning and critical reflection on technological impacts [10], [11].

This absence raises a central question: can the compassionate and caring dimensions of love be taught and conceptualized through a transdisciplinary and holistic design thinking methodology, and serve as a foundation for engineering education? Addressing this question involves exploring how students' broader understanding of love might support its emergence as a way of knowing, relating, and designing.

Philosophically, love is often regarded as a foundational condition for empathy, as it fosters an emotional openness that enables understanding and connection [12], [13]. This openness can, in turn, cultivate compassion, which may lead to caring actions [14]. However, empathy does not always stem from love alone; it can also arise from curiosity, shared experience, or ethical reasoning [15]. Similarly, while compassion is often associated with love, it can also be driven by moral principles or a commitment to justice [16]. Across cultures and relationships, love is expressed through thoughts, emotions, desires, language, and actions, shaping how individuals engage with one another, the environment, and respond to needs.

Building on this philosophical grounding, this paper argues that rooting empathy, compassion, care, and ethical action in a conceptual and practiced understanding of love can enable students and designers to shift design paradigms more profoundly than empathy or compassion alone. Love, in this context, can transcend romantic attachment alone; it is not merely an emotional state or personal affection but an active, sustained commitment to the growth, care, and collective well-being of others [17], [18]. Moreover, this paper extends the concept of love beyond human relationships to encompass non-human entities, emphasizing humanity's profound entwinement with the more-than-human world [19]. It advocates for a wider ecological responsibility, fostering the relational and systemic flourishing of all aspects of nature. While empathy may help students understand others' experiences, love carries that understanding further—into sustained ethical action [20]. It moves beyond momentary identification, prompting student designers to engage more deeply with how their actions shape relationships, environments, and systems—beyond mere reflection or considerations of efficiency or satisfaction.

This expanded view of love also encompasses self-awareness, the ability for students to recognize their values and biases, as well as compassion, understood as a deliberate practice aimed at reducing harm and promoting holistic well-being. Teaching love in engineering, therefore, demands that its biological, philosophical, psychological, and neuroscientific foundations, alongside its cultural expressions in literature and art, and its historical connection to technology, be at the core of students' understanding.

In education, practices of love, care, and trust have long empowered students to become active participants in knowledge creation, particularly through reflective dialogue [21]. Evidence from other fields reinforces the transformative potential of love-informed practices: in healthcare, compassionate models improve patient outcomes through trust-building [22]; in education, relational pedagogy enhances learning by fostering emotional engagement and connection [23]–[25]. While empathy and care have been emphasized in some engineering design courses [26]–[28], this paper argues that engaging students directly with the principles and practices of love can deepen these qualities by cultivating stronger connections among emotional intelligence, ethical reasoning, creativity, and design thinking, understood as form of cognition [29], [30]. These insights suggest that love, as a foundational principle in engineering education, could foster more ethical, reflective, and responsible design practices. While love-informed pedagogy typically shapes how educators relate to students, this paper offers a distinct approach: teaching students about love as an epistemic and design-oriented practice—positioning love itself as a subject of study, reflection, and application. Rather than drawing solely on pedagogies informed by love, this research proposes an approach that centers students' learning of and engagement with love and its attributes.

This paper proposes a conceptual framework of love that can guide both curricular content and daily practice in engineering education. By centering love as a mode of knowing and relating, this model supports the development of self-awareness, relational sensitivity, compassion, and actionable care—qualities essential in an era of technological complexity that calls for deeper attunement to interdependence and ethical responsibility.

Love, as a central focus in engineering curricula, could cultivate a mindset that balances technical expertise, historical perspectives on human values and technological advancement, and emotional connections of care [30]. Applying this perspective to emerging technologies such as artificial intelligence (AI) could prompt students to broaden their ethical frameworks, moving beyond instrumental or anthropocentric theories of technology [31]–[34]. This shift invites student reflection on which aspects of being human we seek to preserve—and which relationships, both human and ecological, remain independent of technology—as it becomes increasingly integrated into our lives and ecosystems. By fostering an awareness of the interconnectedness between technological systems, ecosystems, and diverse species, students may become more attuned to unintended consequences and better equipped for ethical design. As an active force, love could also shape communication and collaboration in design, fostering care and a more expansive vision for diverse forms of engagement.

This research examines the theoretical foundations and classroom applications of love as a core topic of knowledge in secondary and postsecondary engineering education. It explores how love, both as a subject of study and conceptual lens, shapes students' self-reflection, ethical understanding, and relational dynamics in life and design contexts. The paper presents a transdisciplinary framework for love, applies it to holistic design thinking, and outlines the research methodology, classroom insights, and potential for future educational pedagogies.

It positions love and ethics as central to the human condition, emphasizing that ethical development can evolve in concert with the natural world and non-human entities. By integrating love from a human perspective with ethics that encompass both human and more-than-human considerations, this approach could provide a stronger foundation for addressing the ethical challenges posed by technological growth. This approach, if adopted in engineering education, could fundamentally shift students' perspectives—expanding their emotional, relational, communicative, and ethical reasoning beyond anthropocentric technological frameworks. Engineering education, in this view, becomes a site for cultivating students who embrace love as both a lived experience and an actionable commitment—encouraging designers to question the trajectory of technological development while seeking to preserve what it means to be human and to promote holistic care, responsibility, and long-term flourishing across all communities, both human and more-than-human.

Love at the Heart of an Engineering Education: A Philosophical and Conceptual Framework

Engineering education should emphasize the deep connections between love, ethics, design, and technology, offering students a comprehensive understanding of how these forces shape human behavior and drive change. Love, as a multifaceted human experience, is not only an emotional and psychological state but also a relational and cultural dynamic influencing thoughts, beliefs, emotions, and actions [35]. Throughout history, it has shaped human societies, the environment, and technological development, guiding both personal and collective decision-making [36]. Understanding love in this broader sense enables students to recognize how emotional and relational dynamics have shaped both who they are and how technologies are designed—not only to solve problems, but to cultivate connection, meaning, and well-being.

Similarly, design—central to engineering—has always engaged both emotional and cognitive faculties to solve problems and create new possibilities, even when these dimensions are not explicitly recognized [37], [38]. Love, as a relational force, has profoundly shaped the development of design, particularly in the context of survival and cooperation during the Upper Paleolithic and Mesolithic periods [39], [40]. Humans possess a unique capacity to alter their surroundings, creating objects and systems imbued with meanings beyond their natural functions. Early hominins may have conceptualized relational frameworks and folk notions of time, space, and force through observing nature, contributing—through embodied activity—to the development of symbolic systems such as storytelling and to causal reasoning about the properties and functions of materials like sticks, stones, fire, and water [41]. Here, storytelling is seen as an early technology—an object—of emotional and communal survival. These early insights may have laid the cognitive groundwork for psychological understanding and causal reasoning, as illustrated in Figure 1.

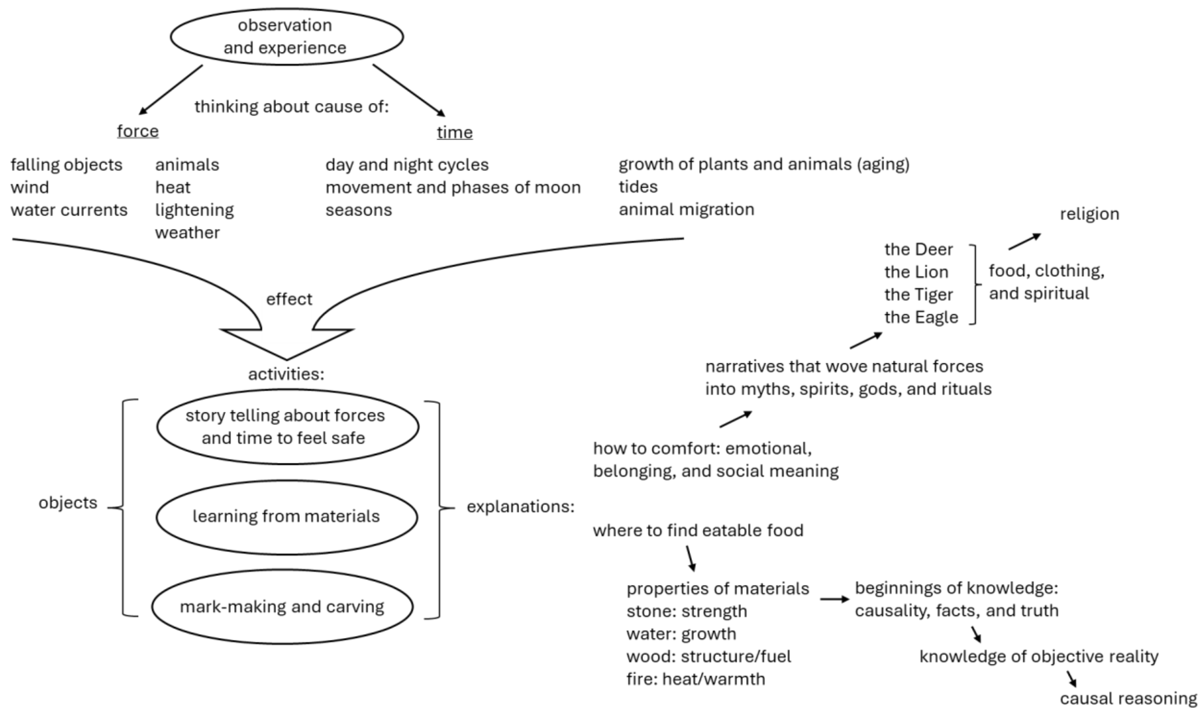

Figure 1. Conceptualization of early human causal cycles from observation and experience

By examining how early objects might have been created and why, students can postulate causal chains of knowledge and culture, gaining insights into the foundational connections between design, emotional motivations, and cultural evolution. This approach encourages students to view technology not only as a series of technical advancements but as deeply intertwined with human development, nature, emotional dynamics, and cultural values.

As humans began making tools and simple technologies for survival, both evolutionary biology and the emotional and cognitive dimensions of love—rooted in empathy, compassion, and care—played integral roles in shaping early design practices in relation to nature [42]. These relational dynamics likely emerged through evolutionary processes that favored offspring survival and the nurturing of social bonds [43], [44]. Archaeological and anthropological evidence shows that early humans formed cooperative groups, which developed technologies such as stone tools, basketry, farming techniques, and shelters [7], [41], [45]. In reinforcing group cooperation and communal well-being, these dynamics contributed to the development of tools and systems that addressed both individual and collective needs [41], [43]. Humans also display reciprocal altruism, extending cooperation beyond kinship to larger social groups [46], [47], with gratitude likely playing a key role in fostering cooperative emotions and behaviors [48]. In this way, love became central to both survival and technological development. Some early human societies practiced cyclical habitation patterns—settling to farm, hunt, and gather before moving on to let the land regenerate—demonstrating a design approach deeply attuned to regenerative rhythms of nature [7]. While technical reasoning guided function, emotional intentions shaped form, infusing early technologies with meaning beyond mere utility [49]. Over time, these dynamics have continued to shape human interactions and our relationship with the more-than-human world. What began as practices rooted in care and reciprocity toward nature has, however, often shifted toward control and extraction, contributing to ecological imbalance. Figure 2 illustrates a conceptual knowledge chain linking love and its attributes to design through experience.

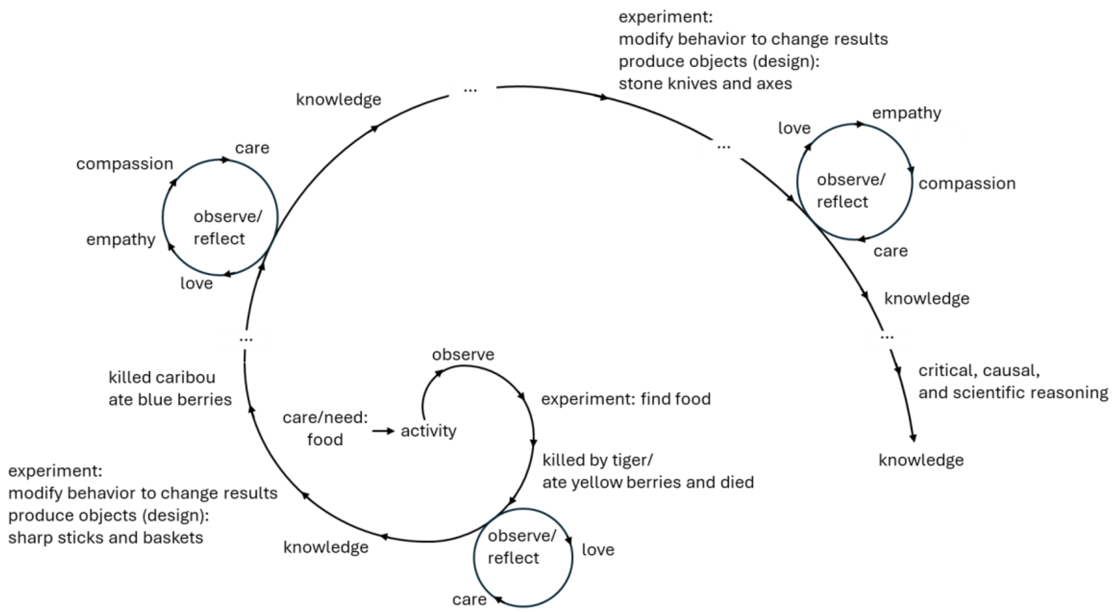

Figure 2. Conceptual knowledge chain between love's attributes and design

This conceptual framework offers valuable insight for engineering students by illustrating how love, empathy, compassion, and care might have manifested in action, influencing human development and technological practices across time. It also aids students in recognizing how these dynamics have evolved through various historical and cultural contexts.

These early human activities engaged psychological processes such as planning, motor control, and observation, illustrating how cognitive and emotional capacities jointly shaped early design and technological innovation. As human cognition evolved, creative expression—seen in cave paintings and animal sculptures—reflected the emotional motivations underlying both technological and cultural development [50]. Over time, traits such as empathy, sympathy, aesthetics, and the use of tools to extend human capability became embedded in human behavior. This convergence of emotional insight, practical reasoning, and imagination forms the foundation of how humans engage in design, where creativity and intuition collaborate to identify needs and generate innovative solutions [51].

Figure 3 conceptually illustrates this cognitive dynamic, showing how sensing, reasoning, and imagination give rise to perception. Through a feedback loop, perceptual expectations are updated in an active process of attention, experience, and memory, leading to causal inferences about the world. Imagination and reasoning—fundamental aspects of human cognition—may have contributed to the evolution of traits such as empathy, sympathy, and moral reasoning, which form the basis of ethical understanding [52], [53].

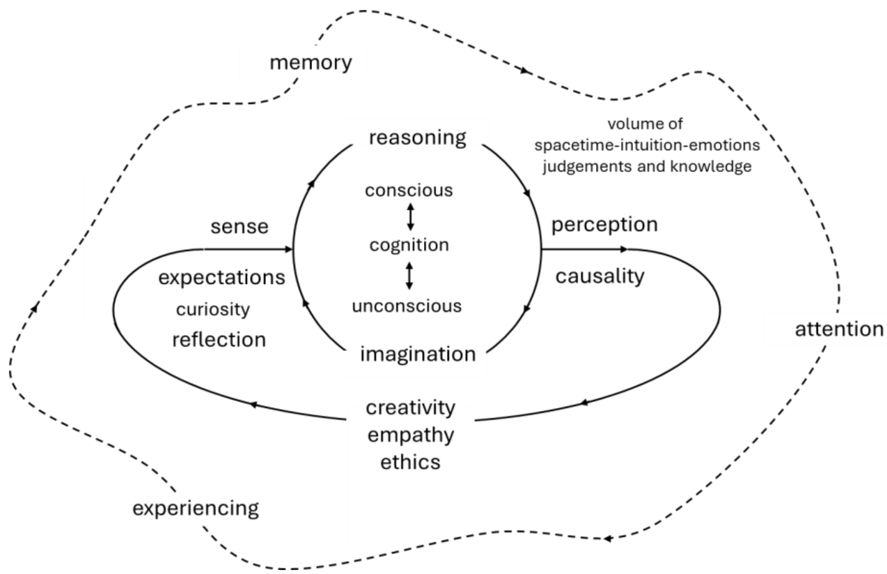

Figure 3. Conceptual interplay between reason and imagination giving rise to causality

This figure helps students understand how cognitive processes relate to empathy and ethics and how they might serve as a foundation for creative processes—highlighting their role in shaping causal understanding and informing design thinking.

While the influence of love on design and technology has fluctuated throughout human history, its potential relational and motivational power could be deeply relevant for engineering education today. Design is not only a technical process but also a social practice—one that shapes how people collaborate, adapt, and engage with their environments. Educators can support students in exploring how values such love and its attributes might influence technological choices and broader social outcomes. Drawing from the humanities and cultural studies may further challenge dominant design paradigms, prompting students to view technology as an expression of ethical commitments and relational values.

The humanities, arts, and social sciences offer valuable insights into how humans experience love, illuminating its complexities, cultural expressions, and ethical dimensions. Across time, love has been recognized as a transformative force—shaping not only personal relationships but also social values and creative practices [54]. Ancient Western philosophers such as Empedocles, Plato, Lucretius, Seneca, and Plotinus examined love in its many forms—familial, fraternal, and self-love—emphasizing its role in fostering harmony, unity, and reflective thought [55]–[57]. These ideas resonate with engineering concerns around teamwork, ethical awareness, and collective responsibility in design. Similarly, Shakespeare's sonnets and plays portray love as a dynamic force that fuels connection, imagination, and moral questioning [58]. His work reveals how love can inspire empathy, challenge convention, and expand human understanding.

In parallel, sacred texts such as the *Bhagavad Gītā* explore love through the lenses of bhakti (devotional love) and karma yoga (selfless action), emphasizing love and care as guiding principles for ethical conduct, ecological harmony, and alignment with a greater whole [59]. Likewise, the *Tao Te Ching* frames love not as sentiment or control but as attunement to the natural flow of life [60]. Its principle of wu wei—acting in harmony with nature rather than against it—offers a powerful metaphor for relational design, ethical restraint, and ecological balance in engineering practice. These philosophical and literary traditions offer students critical insights into love as a relational force that extends beyond individualism, encouraging them to view design and technology not merely as tools for solving problems, but as a medium for shaping relationships, responsibilities, and ways of being.

Cultural records from early civilizations further illuminate love's formative role in social life, values grounded in the natural world, and communicative and creative practices. Ancient writing systems such as cuneiform and hieroglyphics documented expressions of love in both romantic and communal contexts. For instance, the "Love Song for Shu-Sin" (c. 2000 BCE) from Mesopotamia ties love to fertility rituals and collective survival [61], while Egyptian love poetry (c. 3000 BCE) links affection to nature and the flourishing of community life [62]. These sources reflect how love historically motivated actions that sustained both human and environmental systems—an understanding that resonates with contemporary calls for ethical and holistic approaches to design [30].

Building on these historical foundations, the cognitive dimensions of love further illustrate its role in shaping ethical and design-oriented actions. Figure 4 conceptually illustrates how, in cognition, love—imbued with empathy, where empathy emerges through perceptual expectations and causal inferences—gives rise to compassion, care, action, and design.

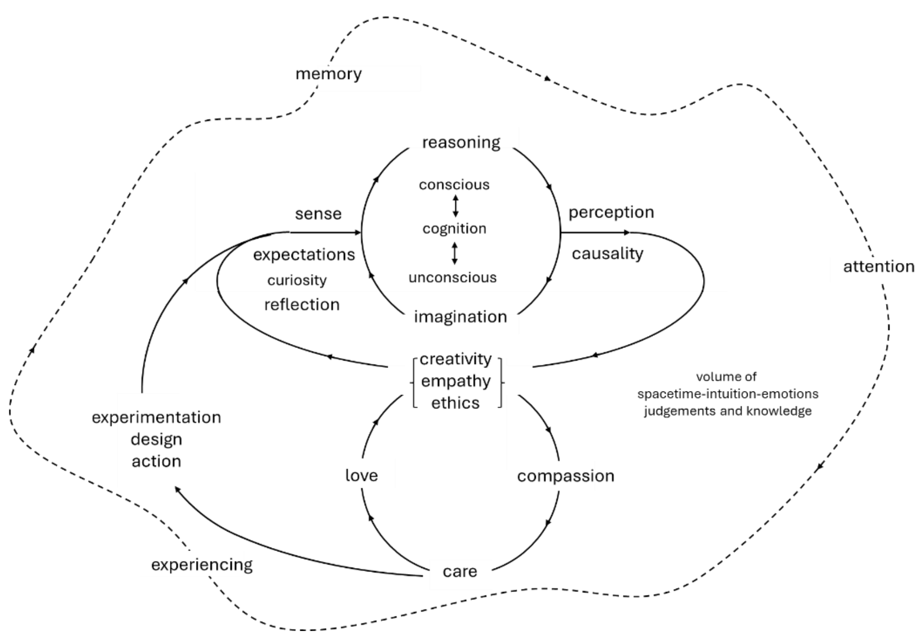

Figure 4. Loves connection to empathy, compassion, care, and design

This visualization distills key ideas about love's role in empowering empathy and compassion, and through caring action, its influence on design. It helps students reflect on how relational and emotional cognitive dynamics shape processes of creative synthesis and ethical judgment. Love, acting as a cognitive guide, can inspire a moral compass that encourages students to prioritize compassion and ethical solutions, fostering a deeper emotional resonance that leads to actions grounded in empathy and care, rather than purely rational or utilitarian logic, and cultivating a profound sense of duty and responsibility.

Psychological research underscores how love shapes human relationships by promoting cooperation, ethical decision-making, and emotional regulation [63]. Love's emotional, cognitive, and behavioral dimensions highlight the diverse ways it is experienced and expressed, offering a deeper understanding of its role in human development. A key factor in this process is compassion, which integrates sympathy, empathy, concern, and a desire to alleviate suffering [64]–[66]. Unlike empathy, which involves either emotionally sharing or cognitively understanding another's feelings, compassion includes a motivational drive to act, prompting individuals to provide care and support [67]–[73]. Compassion can emerge from this empathetic understanding, as it nurtures emotional bonds and fosters the relational dynamics characteristic of love [64], [65]. Additionally, attachment plays a central role, incorporating attraction, intimacy, affirmation, and support, as well as relational elements like commitment and communication [74], [75]. These qualities work in tandem with emotional regulation, beliefs, expectations, reciprocity, altruism, and self-esteem to sustain and deepen relationships [72], [73]. Together, they form a complex network that underpins love's profound influence on human development. These insights align with foundational theories of motivation and growth, where love and compassion are not merely relational forces but essential components of self-actualization and social responsibility [76]–[79].

In *The Art of Loving*, Erich Fromm (1956) describes love as an orientation of character that shapes how individuals relate to the world [80]. He argues that self-love—alongside care and respect for others—is essential for both personal and professional growth. Students come to better understand and more deeply appreciate self-love by learning about the role of parents and caregivers in early childhood development—particularly in shaping self-love, object permanence, and healthy boundaries through the accurate mirroring of emotions [81]–[85]. They also explore how the functions of love are expressed in distinctly human ways. Students examine how deep understanding can emerge through the experience and practice of compassionate love [86]. Similarly, Abraham Maslow's hierarchy of needs positions self-esteem as a key driver of motivation and achievement, with self-love serving as its foundation [78]. Self-love fosters introspection and self-reflection, supporting the discovery of one's talents, the pursuit of goals, psychological well-being, and the capacity to build meaningful connections.

For students, understanding the inner dimensions of love—defined as the absence of indifference—is closely tied to developing compassion and care. Building on this foundation, students scaffold new insights about love and care onto their existing conceptual frameworks, integrating this knowledge into valued structures of understanding. This process enables them to reflect on and reorganize their assumptions, aligning emotional insight with a holistic design methodology grounded in love and ethics.

The psychological aspects of love—sympathy, empathy, compassion, and care—are essential not only for sustaining human relationships and societies but also for driving acts of creation, problem-solving, and innovation. These emotional dynamics extend beyond human relationships to encompass non-human entities, such as animals, ecosystems, and the environment. The intrinsic desire to alleviate suffering, foster emotional security, and promote well-being can manifest in practical actions, such as designing tools, technologies, and systems that serve not only functional purposes but also ethical and compassionate goals [87].

In *Awakening Loving-Kindness*, Pema Chödrön explores love from a Tibetan Buddhist perspective, emphasizing how love motivates ethical action and reveals our interconnectedness with all beings [88]. This view aligns with Buddhist teachings, such as those found in the *Dhammapada*, which describe love through mettā (loving-kindness) and karuṇā (compassion) [89]. These teachings frame love as an active practice grounded in non-harming, interdependence, and mindful awareness—principles that resonate with ecological thinking and relational ethics in design. They provide students with a lens to view engineering not merely as technical work, but as an opportunity to cultivate compassion, relational awareness, and systems thinking that support both environmental harmony and more-than-human flourishing.

This interplay between emotion and action also aligns with findings in evolutionary biology and the psychology of social behavior [90]. While natural selection has favored competition, it has equally supported cooperation, generosity, and prosocial tendencies [91]. In *How the Mind Works*, Steven Pinker frames this balance as a “difficult engineering problem”—a complex negotiation between competitive and collaborative impulses shaped by neural design and evolutionary pressures [92]. For engineering students, understanding these evolutionary tensions offers valuable frameworks for exploring the ethical dimensions of their work, particularly in relation to collaboration, interdependence, and responsibility.

Engineering as a profession embodies this duality: it creates technologies and systems designed to address both human and ecological challenges, while simultaneously giving rise to new ethical, environmental, and societal dilemmas. This is particularly evident in the ways technology is employed—on the one hand, to support economic sovereignty and national security; on the other, to advance global cooperation, educational access, public health, and environmentally neutral energy systems. This dual role mirrors the evolutionary tension between competition and cooperation—what Pinker refers to as a “difficult engineering problem.” In this context, engineering is not only influenced by such tensions but must actively engage in resolving them. These contradictions are also mirrored in the way engineering is taught, where an emphasis on rigor, precision, and analytical thinking often frames solutions as singular and objective, leaving little room for ambiguity, empathy, or negotiation.

By examining these historical evolutionary aspects, students can gain insight into how design has consistently been shaped by emotional and relational dynamics. Understanding this history reveals how these forces can inspire innovative approaches to addressing contemporary challenges with care and ecological consciousness. Viewed through the framework of love, its attributes, and technology, this history provides valuable perspectives on how the psychological dimensions of love can transform current design practices and relational dynamics.

Compassion's Extension to Nature in Engineering Education

Extending students' compassion to nature—both living and non-living—remains a challenge within complex, technology-driven systems and dominant models of engineering education [11]. As engineering affects the environment at every stage—from resource extraction to long-term degradation—integrating ecological principles across engineering curricula is essential for fostering systemic change [93].

Humans' ability to adapt is rooted in visual thinking, abstraction, and goal-directed reasoning—transforming matter for practical purposes that began with a deep relationship with nature [94]. Yet technological advancement has distanced us from nature, rendering it an abstraction encountered through digital screens rather than through direct, embodied experience [95].

This disconnection raises a critical question: While we may empathize with ecological crises, do we feel a moral imperative to act on that empathy? Students would benefit from a curriculum that not only examines the profession's role in ecological loss but also encourages compassionate reflection on their personal impacts. As historian James Burke [96], [97], suggests, technological interconnectedness accelerates innovation, but when this acceleration outpaces human adaptability, what are the consequences for agency, liberty, and privacy?

This paper suggests that as technological systems hasten change, they instigate instability in social structures and ecosystems, fostering a profound disconnection from nature. As people devote more time and attention to technology, their focus shifts away from environmental health, exacerbating the Anthropocene. This shift from the physical, grounded world to a digitally mediated way of being further accelerates ecological decline.

To foster a more meaningful connection to nature, engineering education could incorporate emotionally resonant, historically informed, and culturally diverse perspectives that foreground ethical and sustainable design. In *The Spell of the Sensuous*, David Abram argues that modern societies have become increasingly disconnected from their sensorial and embodied relationships with the more-than-human world [19]. He maintains that this reciprocal relationship with nature is vital to our perceptual vitality—suggesting that it is through this connection that human beings remain fully sentient, grounded, and responsive to the living world.

This paper proposes that although humans emerge from the non-human-made world of nature, engineering has expanded the domain of the more-than-human to include technological systems—entities that now operate alongside natural processes, sometimes intensifying, disrupting, or abstracting from them, often without adequate consideration of their ecological or ethical implications [98]. The usage of the term more-than-human has been extended to include complex technological systems, such as AI-driven infrastructures [99]. This raises a critical question: How might the ethical framework of holistic design—with its emphasis on love and the extension of moral value to the natural world—apply to machines? While this paper does not focus on that extension, it remains an essential issue for engineering students to consider, particularly in light of postnatural conceptions of nature, where human-made systems are viewed as part of, rather than separate from, the natural world. Such perspectives invite important ethical reflection on agency, responsibility, and the potential extension of moral consideration to technological entities [100], [101].

Engineering students could also gain deeper insight by examining the extent to which contemporary practices distance the human mind from its historically embedded relationship with the natural world. The consequences of this disconnection are increasingly observable, particularly among children, who have fewer opportunities and diminishing inclinations to engage with nature—due in part to the competing presence and allure of digital technologies [95], [102]. Students could be further supported by engaging with works that articulate a deep reverence for nature, including the contributions of artists such as Monet and Audubon, naturalists like Muir and Thoreau, poets including Wordsworth, Dickinson, and Whitman, and scientists such as Carson and Wilson. These perspectives suggest that love for nature transcends disciplinary boundaries and provide compelling models for holistic environmental understanding [103]–[111].

Advanced systems technologies, often framed as universal solutions, can obscure risks—such as social inequality, addiction, and detachment from the natural world [112], [113]. Communication technologies that enable connection are also embedded in AI systems that foster dependency and constrain choice. To counter these effects, students should learn to practice love-based, empathetic, and compassionate thinking in both classroom practices and applied design. This would encourage them not only to critically and holistically examine the consequences of the technologies engineers create but also to periodically disconnect from digital systems and reconnect with nature, cultivating care that extends beyond human concerns and supports ecological balance and environmental stewardship.

Reclaiming Design Through Love, Compassion, and Care

Critical scholars have argued that as emotional and relational dynamics evolved alongside technological development, political and economic power structures co-opted love and care to reinforce systems of patriarchy and hierarchy [17], [114], [115]. These dynamics have shaped technologies that prioritize control, efficiency, and profit over collaboration, reciprocity, and relational well-being [116]–[118]. Concurrently, insights from neuroscience and psychology have informed the design of technologies that position humans as commodities within consumer societies [119], [120]. For example, while phones were originally intended to foster communication and connection, contemporary mobile devices often serve as tools for data extraction, surveillance, and behavioral exploitation. AI-driven algorithms now manipulate attention, desire, and social interaction to serve governmental and corporate interests—often at the expense of collective well-being.

This shift reveals how emotional needs can be engineered and redirected toward consumption and control, rather than mutual care or collective empowerment. Within dominant capitalist and industrial systems, design is frequently driven by profitability, reinforcing extractive models that marginalize emotional depth, ecological stewardship, and reciprocal relationships. These patterns reflect broader paradigms—such as neoliberal capitalism, the military-industrial complex, colonial extractivism, planned obsolescence, and technocratic rationalism—that commodify not only natural resources and labor but also human emotion and connection [116], [121].

In contrast, diverse traditions—including Indigenous knowledge systems, cooperative economies, and non-exploitative modes of production—offer alternative approaches grounded in care and reciprocity. Within these traditions, love—understood as both care and creative desire—provides a framework for challenging dominant logics of efficiency, control, and commodification. Across cultures and histories, love has informed design as compassion (the drive to alleviate suffering) and as creative desire (the impulse to make meaning and foster belonging). As a generative relational state, love cultivates responsibility and attentiveness, guiding designers to respond to both human and more-than-human needs.

Here, compassion is not merely an ethical impulse but a character stance—one that resists dehumanization, environmental degradation, and technological manipulation. It can inform the design of inclusive public spaces, counteract exploitative behavioral technologies, and support sustainable products aligned with ecological well-being [64], [91], [93], [122].

While many engineering textbooks frame design around technical specifications, they often overlook its emotional and ethical dimensions [123]. The phrase Design Thinking as a design process emerged in the 1950s, emphasizing the unlocking of creativity and empathy in engineering students [124], while later contributions highlighted the importance of addressing emotional, intellectual, physical, and sensory needs [125]. In contrast, design thinking refers to a human cognitive process involving the mental framework used in design problem-solving.

Empathy is now widely recognized as a cornerstone of Design Thinking, enabling designers to understand users' experiences [125]. It has become increasingly valued in engineering education and human-centered methodologies [126]. Yet empathy alone is insufficient; it can be distorted by unconscious bias or cultural blind spots [73]. Compassion—an action-oriented form of empathy grounded in love—guides the ethical and ecological dimensions of design by fostering deeper listening, reflexivity, and accountability. It encourages designers to challenge assumptions, recognize diverse ways of knowing, and expand the scope of design to embrace holistic valuing. While human-centered design typically begins with empathy [127], integrating love, care, and compassion—alongside insights from psychology and neuroscience—could transform student design thinking into a more relational and holistic practice. Understanding the interplay between emotional and rational cognition supports richer, more grounded approaches to engineering design. Where empathy helps designers feel with others, compassion motivates them to act.

For instance, a designer empathizing with flood-prone communities may understand their fears, but compassion—rooted in love—can inspire a deeper sense of care, prompting the designer to embed themselves within and engage directly with both the community and the surrounding ecological systems to co-create solutions that address the social and environmental dimensions of climate change.

Love deepens awareness of interdependence, while compassion activates that awareness through inclusive, ethical action. A love-centered, holistic design relationship can also help students understand their role as protectors of human dignity—recognizing neurodivergent ways of being not as problems to be fixed or erased through future technologies like CRISPR or neural interfaces in pursuit of a perceived norm, but as differences to be respected and supported.

Holistic design thinking reorients design paradigms by centering love and compassion as relational foundations, advancing a more interconnected understanding of humans, nature, and technology. By exploring how love can reshape engineering relationships, educators, students, and practitioners can reimagine design as a practice grounded in care, sustainability, and justice.

Love as a Starting Point in Holistic Design Thinking

Love has been proposed as a starting point for a Holistic Design Thinking (HDT) methodology [20], [30]. Grounded in a pedagogy of transdisciplinary knowledge and holistic practice [20], this methodology challenges traditional engineering education by positioning love, its attributes, and related ethical commitments as both the starting point and the guiding core of the design methodology taught and practiced by students.

HDT integrates these principles within a continuous, cyclical relationship—acknowledging that design is not a linear progression, but an ongoing process of reflection, evaluation, and adaptation based on interaction. Its framework is responsive to both human and ecological needs. It invites students to engage through iterative cycles of experience, reflection, abstraction, evaluation, and refinement, ensuring that design practice remains ethically grounded and emotionally attuned. Figure 4 illustrates this dynamic relationship, highlighting the enduring centrality of love and ethics in HDT.

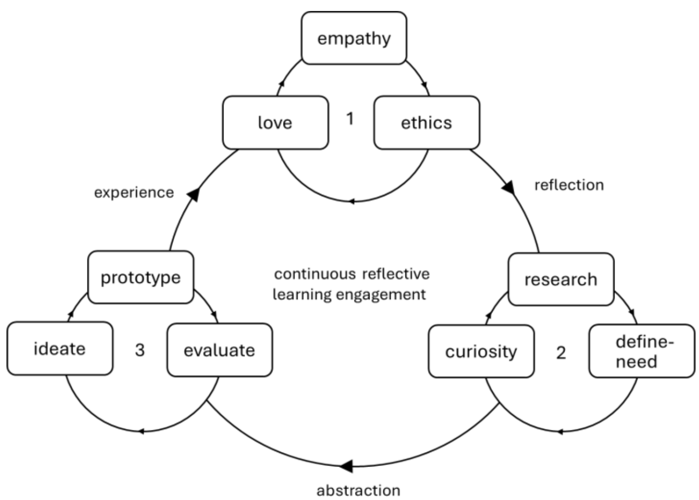

Figure 4. Holistic Design Thinking relationship

HDT is defined by its iterative structure, consisting of three main cycles: (1) understanding, (2) observing, and (3) resolving needs. Importantly, "resolving" does not mean fulfilling every human or machine requirement; rather, it involves critically evaluating long-term implications across ecological and social systems—and, when necessary, choosing not to proceed with a design. This approach helps ensure that technological development is not treated as value-neutral but is ethically examined for its holistic impacts. Each cycle informs the next and the previous, allowing the design to evolve with growing ethical awareness and a commitment to more-than-human relationships and responsibilities.

The first cycle of HDT centers on love, empathy, and ethics in identifying needs. Figure 5 illustrates the micro-cycle of love that guides this initial stage of ethical understanding and design engagement.

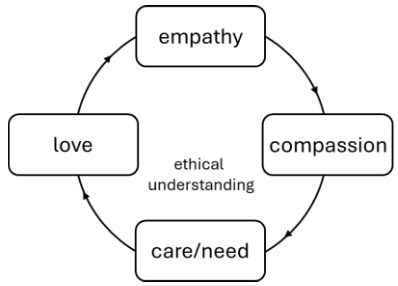

Figure 5. Micro-cycle of love in ethical understanding

This micro-cycle examines the relationship between love, empathy, compassion, and care in recognizing, understanding, and defining needs. HDT emphasizes that love is not merely an abstract ideal but an actionable force that fosters introspection, ethical reflection, and collaboration in design resolutions.

The second cycle builds on the first by centering curiosity and research, leading into a third cycle of ideation, prototyping, and evaluation. Designers move fluidly between analysis, synthesis, and reflection, enabling continuous refinement and ethical awareness at every stage. Rather than simply solving problems, the cyclical structure fosters creativity, philosophical inquiry, and ongoing ethical engagement. This iterative approach reinforces a dynamic relationship between the designer, human communities, and the more-than-human world. As students move through each cycle with collaborators, they refine their thinking through reflection, aligning their work with compassionate and ethical aims. Figure 6 illustrates this progression, with dashed lines representing the nonlinear interconnectedness across cycles.

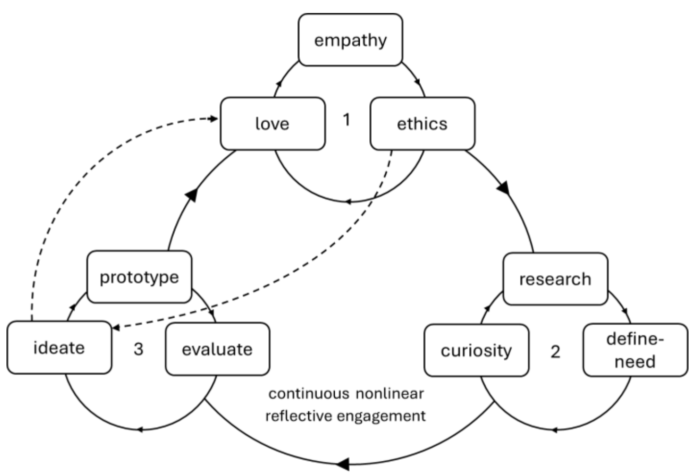

Figure 6. Continual access to cycles of assessment within the nonlinear relationship

The figure illustrates how these cycles interconnect, enabling designers to revisit earlier phases, respond to emerging insights, and iterate toward loving and ethical resolutions. This nonlinear approach is essential for navigating complex system design challenges, where solutions must evolve through ongoing reflection and adaptation rather than being predetermined. HDT positions design as a relational act—one that acknowledges interdependence and the need to value human and ecological relationships.

Ultimately, incorporating love- and compassion-informed principles into engineering education invites students to move beyond problem-solving toward care-driven innovation—resolving issues collaboratively with humility, a sense of interconnectedness, and a long-term commitment to the well-being of all life.

Research Methodologies

This study builds on the previously established conceptual framework that begins engineering education with the study of love, using this perspective to explore empathy, compassion, care, ethics, design, and engineering. It focuses on whether treating love not as a supplementary theme but as a foundational lens can be conceptualized, taught, and implemented within transdisciplinary knowledge frameworks in secondary and postsecondary engineering courses. Specifically, it examines how this approach might deepen students' understanding of love, empathy, and ethics in relation to technology, design, and engineering practices.

The research investigates how framing love as both a subject of study and a guiding principle in design influences students' perspectives on design thinking, interpersonal relationships, and ethical responsibility. It also explores how the qualities associated with love—such as self-love, communication, and care—can deepen collaboration, trust, introspection, self-reflection, and ethical reasoning within team-based design thinking.

This part of the study considers how such qualities inform a relational pedagogy in engineering education and influence students' holistic understanding of design and professional identity as engineers. To explore these dimensions, the study addresses the following questions: How do students engage with, perceive, and respond to the study and practice of love, empathy, and ethics as central to engineering education, including any challenges or resistance they encounter [RQ1]? How does this engagement shape their understanding of these concepts and their relevance to engineering [RQ2]? How do students' attitudes toward engineering shift when they engage with relational and emotional content [RQ3]? What are the broader implications of beginning engineering education with love, empathy, and ethics—for both individual students and the discipline [RQ4]?

To investigate these questions, a range of qualitative methods were used [128], including classroom observations, student work artifacts, conferences, interviews, and surveys. Survey data were collected through the university's course feedback system, which gathers insights to improve teaching and learning. Longitudinal secondary data were also gathered post-graduation through follow-up interviews to explore students' longer-term reflections on their learning experiences.

Subjective and qualitative findings were analyzed using comparative and contextual approaches to examine interactions between relational dynamics and pedagogical strategies. These analyses were aligned with the research questions and aimed to generate theoretical insights into transdisciplinary relational teaching and its impact on students' cognitive and emotional development.

Given the personal nature of love, qualitative methods—particularly interviews and group dialogues—were essential to capturing participants' lived experiences, emotional responses, and motivations. Responses were categorized within transdisciplinary knowledge frameworks, linked to pedagogical outcomes, and examined for trends and patterns using theory-building approaches. Causal relationships were considered in the context of observed interactions.

By centering student experience, this methodology supports iterative cycles of reflection and refinement in engineering pedagogy. The findings offer practical insights into how beginning with love as a way of knowing and being can enhance student engagement, ethical understanding, and relational awareness in engineering education.

Application

The transdisciplinary focus on love as a foundational element in student learning, paired with the use of a Holistic Design Thinking (HDT) methodology rooted in love, has been applied across various educational levels. These include eight senior-level, year-long secondary courses, seven single-semester undergraduate courses, and four graduate-level courses. Additional applications included junior high courses, capstone projects, and independent studies. Elements of pedagogy and methodology continue to evolve and have been extended into postsecondary transdisciplinary honors courses.

At the secondary level, students from several different public schools met for half-day sessions at an off-campus location throughout the entire fourth year of high school. The secondary experience was based on a holistic and transdisciplinary pedagogy that also fulfilled public school credits in engineering, English, economics, and civics [20]. Postsecondary courses were developed through a three-year pilot program available to all engineering majors as electives at a private university. Undergraduate and graduate interdisciplinary courses typically spanned one semester (with some design projects extending over two). Class sizes were small (typically fewer than 10 students), allowing for a focus on emotional and cognitive development, as well as individualized feedback and mentoring.

The instructor developed the pedagogy and curriculum and taught all courses. They held a Ph.D. in engineering, with professional experience in research, design, systems, and project engineering, as well as managerial roles. Their teaching and mentoring experience spanned both secondary and postsecondary levels, supporting the implementation of transdisciplinary, reflective, and relational pedagogical practices.

The pedagogical philosophy includes a conceptual framework that positions love as the core of engineering education. Rooted in holistic education and informed by constructivist and experiential learning theories, neurobiological models of learning, relational ethics, affect theory, and more-than-human perspectives, this approach positions love and its attributes as foundational knowledge—shaping how students engage with ethical reasoning, collaboration, and design [19], [25], [76], [129]–[132].

A host of pedagogical tools were employed, including reflection circles, dialogues, mentoring, individual conferences, and a digital-free classroom environment that emphasized analog practices. The consistent use of analog tools across all aspects of student learning helped promote focus, sustained attention, self-awareness, and intrinsic motivation. Central to the analog practice is a blank-page notebook, which students use to document experiences both inside and outside the classroom—including observations, thoughts, reflections, ideas, experiences, notes, sketches, coursework, ideation, and design concepts. Rooted in holistic education principles, this tool fosters nonlinear thinking and creativity, engaging both cognitive and emotional processes [20],[30]. By allowing students to express their thoughts and feelings through a range of practices, including reflective writing and sketching, the notebook serves as a valuable outlet for emotional and cognitive expression. This practice aligns with the neurobiological model of learning, which emphasizes the integration of emotional and cognitive faculties to enhance learning outcomes. Through this process, students cultivate self-awareness and emotional intelligence—fundamental components of the holistic approach to education—and deepen their understanding of design thinking.

Other core practices include cultivating awareness of emotional and cognitive engagement; participating in daily, instructor-facilitated reflection circles; engaging in analog critical reading with annotation and marginalia; and practicing reflective, analytical, and critical writing. Students also develop collaborative communication skills through perspective-taking, active listening, empathetic listening, dialogue, presenting ideas and work, ethical analysis, and design projects—complemented by time outdoors.

The first transdisciplinary knowledge domains introduced—love and its attributes, modes of thinking, communication theory, and ethics—are explored as foundational to the curriculum. These areas help students build emotional intelligence and cognitive depth, setting the stage for more complex work with relational dynamics and design thinking. The curriculum then uses this foundation to provide broader transdisciplinary knowledge before gradually transitioning this integrated awareness into individual exercises, structured design problems, and eventually, real-world projects—where insights from these foundational domains support collaborative, context-sensitive solutions.

Through this pedagogy, students develop fluency in design thinking while engaging flexibly with critical, causal, visual, scientific, and other modes of thinking and inquiry, learning to recognize how everyday habits, behaviors, and interactions involve design thinking, shaping both relationships and social patterns. Early emphasis on self-love, self-awareness, intrinsic motivation, compassion, and character nurtures personal growth and lays the foundation for meaningful teamwork. Practices such as empathetic listening and reflective dialogue deepen emotional awareness and illuminate relational power dynamics, preparing students to engage design challenges with ethical and compassionate sensibilities. Design is framed as inherently relational—rooted in how individuals treat themselves, others, and the environment—where compassion is emphasized as essential to collaborative problem-solving.

After establishing a foundation in the integration and synthesis of knowledge across multiple disciplines, students engage in real-world design projects that emphasize relational and causal principles, as well as collaboration—without relying on computerized or prepackaged technological tools. The designed outcomes—whether a tangible object or a conceptual idea—are not the central focus; rather, they serve as a context for building and practicing relational dynamics. Grounded in a transdisciplinary, constructionist pedagogy, the approach emphasizes student-centered, active, and cooperative learning. It employs relational methods to explore how interpersonal dynamics and emotional responses influence engagement. By fostering self-awareness and empathy, the methodology supports compassionate, team-based learning—especially as students encounter increasingly ambiguous, complex, and open-ended design challenges.

All courses brought together students with diverse disciplinary interests—including various branches of engineering alongside other academic fields—creating a dynamic and integrative learning environment. Drawing from the humanities, social sciences, physical sciences, architecture, and engineering, the curriculum supported holistic learning and enabled students to approach complex design problems from multiple perspectives. This integration and sustained engagement across transdisciplinary forms of knowledge provide the foundation for student learning and engagement in HDT, fostering a more relational, reflective, and ethically grounded approach to engineering education.

Assessment strategies in the courses were designed to cultivate students' intrinsic motivation and self-awareness. These included rubrics, periodic checkpoints, self-assessments, and individual student–instructor conferences, along with formative input from peers and outside professionals. A central focus was on developing students' capacities for self-love, introspection, and personal growth.

Weekly prompted written reflections invited students to evaluate their learning, identify areas for growth, and develop action plans, which were then discussed during one-on-one conferences. Students then implemented these action plans, testing them out in practice, which became an integral part of the ongoing cycle of reflection, feedback, and refinement. This process supported academic progress while fostering relational and emotional intelligence, ethical reasoning, and a deeper sense of life purpose.

The courses described in this study were implemented within unique and often fragile educational ecosystems that may be difficult to replicate due to structural and contextual constraints. These include economic limitations (e.g., small class sizes), political hesitancy (e.g., resistance to framing love as a core subject in engineering education), and institutional factors such as time constraints typical of single-course offerings and variability in instructor experience.

Results

The pedagogy has been implemented across a range of engineering courses, including undergraduate, graduate, and secondary-level offerings. While transdisciplinary outcomes for secondary graduates and postsecondary students have been examined in previous publications [29], [30], this paper extends the conceptual framework and analysis by focusing specifically on how students' study and practice of love—and its attributes—impact their relationship with design, engineering, and technology.

The results presented here address the research questions [RQ1–RQ4], focusing on how love, empathy, and ethics are examined and practiced within engineering education, and how these concepts shape students' self-awareness, design thinking, and relational dynamics. These results also contribute to evaluating the conceptual framework underpinning the pedagogy. Given the interconnected nature of the qualitative findings, strict categorization by individual research questions is not fully feasible. Instead, a contextual approach is employed to explore patterns in students' thinking, language, and expressions—both individually and in group interactions—as shaped by pedagogical strategies. Visual anchor callouts are used to link specific responses to the corresponding research questions. A central finding is that concepts such as love, empathy, ethics, and design often appear entwined in students' perceptions of engineering.

Longitudinal interview data from graduates of the secondary program reveal that while "love" was occasionally self-selected as a valued form of transdisciplinary knowledge, "empathy" and "ethics" were selected far more frequently. The themes most emphasized overall were the Holistic Design Thinking (HDT) methodology and critical reading. Notably, students' appreciation for critical reading increased significantly from secondary to postsecondary levels. Although love, empathy, and ethics are central components of the modes of knowledge taught and the HDT methodology, the comparatively limited emphasis students place on love as a standalone concept may suggest that they perceive it as less relevant to engineering practice as they advance through college. This trend may reflect broader societal norms in which love is seldom foregrounded in academic or professional contexts.

This perception may begin early in students' educational experience. Some secondary students initially expressed discomfort engaging with the theme of love in an engineering setting. One student remarked, "The first book that we read in the class was called *A General Theory of Love* [133]. At first, I thought it was a bit of a joke to be reading that in an engineering class when all I had ever been taught about engineering was that you needed to be creative and have a mathematical brain." Such expressions of unease underscore the cultural and disciplinary challenges of introducing traditionally non-technical values, such as love, into engineering education. The more frequent selection of empathy and ethics may reflect a stronger perceived connection between these values and conventional engineering goals. [Relates to RQ1]

In a written reflection on the first chapter of *A General Theory of Love*, another secondary student commented on the psychological and social consequences of poor relationships, noting, "in the absence of good relationships, one can become satisfied with bad ones." They linked this idea to the quote, "If you aren't served love on a spoon, you learn to lick it off a knife," emphasizing the importance of understanding how attachments form and how self-worth develops—both from psychological and neurobiological perspectives. The student framed these insights as foundational to maintaining curiosity, well-being, and the self-reflective capacity needed to engage meaningfully with complex engineering challenges. Another student framed learning about "love as necessary for having compassion for yourself, for self-love." [Relates to RQ1 and RQ2]

Keyword analysis revealed that "love" appeared approximately half as often as "empathy" and "ethics" in student discourse. However, qualitative data suggest that when students did reference love—particularly in conferences and reflective writing—they often did so with a passionate connection between love, life skills, and engineering practice. These reflections were described as shaped by their evolving relationship with the curriculum, a deeper and more connected understanding of concepts, and their peer interactions, especially in terms of how love could inform their approach to design. In working with the HDT methodology, students said it "reshaped my understanding of the missing intricacies of my concepts about being an engineer" and "the better you can interact and connect with others the more of a positive impact you can have on each other's lives." Notably, non-prompted reflective writing produced more frequent and nuanced references to love compared to non-prompted in-person responses. [Relates to RQ4]

Despite some students' initial skepticism, many ultimately described their experiences with love being taught in an engineering course as transformative. One student reflected: "Many new and important lessons about how to approach problem-solving… considering ethics and love before making decisions." Another spoke of a renewed commitment to "making a positive impact on the world through engineering," emphasizing that "the design process we learned is based so much on empathy and ethics because of the responsibility that engineers have when designing and developing solutions." Students also reported applying these principles beyond the classroom, noting efforts to integrate "ethics and love into all aspects of engineering and even everyday life." Such responses suggest that students not only internalized key concepts but also experienced character development through this pedagogical approach. For example, a third-year postsecondary student wrote in a survey that they continued to deepen their understanding of how empathy relates to character. [Relates to RQ1 – RQ4]

Through exposure to the curriculum, students began to recognize the unexpected role of love in engineering, "The first super surprising thing I learned from the class is just how involved love is in engineering. To be able to help others and fulfill their needs, you need a base of love that then leads into empathy." The connection between love and empathy—which can foster compassion and care in action—was highlighted in several student reflections and supported by observational data. For instance, after learning and practicing distinctions between dialogue, discussion, and empathetic listening, secondary students reported using these strategies to resolve conflicts at home, including with a parent. This demonstrated the interplay between love, empathy, compassion, and communication. Similarly, a postsecondary student described applying these skills to navigate conflicts with roommates. [Relates to RQ1, RQ3, and RQ4]

Reflections also indicated a growing awareness of interconnectedness. One student wrote, "We learned just how connected we are to each other and how connected love is to everything we do, even engineering." Another reflected, "[The course provided] a far deeper understanding of what love actually is and how it can be used when engineering the needs of others." Others emphasized the link between personal development and empathy, noting "the importance of learning to love yourself. Once you trust yourself and can properly self-reflect on mistakes, you can learn how to love yourself and then empathize with others." [Relates to RQ1, RQ2, and RQ3]

This association between self-love and the capacity to understand others appeared frequently, suggesting that self-awareness may enhance students' ability to learn and collaborate. A second-year postsecondary student noted how they recognized their decreased ability to focus and improved it by recalling their experience with critical reading strategies from the secondary program. [Relates to RQ4]

By emphasizing love, its attributes, and ethics, the curriculum helped students internalize these values as central to meaningful design. The approach also appeared to promote intellectual humility and care, preparing students to engage with the world in emotionally and ethically attuned ways. In a postsecondary undergraduate adaptive vehicle design project for a kindergartener with a neurodevelopmental delay, the elementary student, seated in the vehicle, hugged one of the design students, bringing them to tears. "For me, it was the first time interacting with children, and to be able to build something for them, to help advance their social skills, seeing it in action was... unspeakable. I'm not able to use words at the moment... to see it all come together, work, and move—it brought tears to our eyes." Similarly, in another instance, a secondary graduate, during a summer internship, described using self-awareness and empathy to guide a group of interns during ideation toward a proposed solution, which was ultimately chosen by management. [Relates to RQ3 and RQ4]

One student reflected, "[This course] taught me so many valuable skills about empathy, love, ethics, and creativity that I would not have gained elsewhere." Interviews revealed that the pedagogy created a supportive environment where students could reflect on and apply these values in design contexts. [Relates to RQ4]

Several postsecondary students have continued to mention that the course helped them "figure out what to do in life," emphasizing the importance of mentoring and student conferences. Another student described the course as teaching the "principles of life," noting that the small "learning community helped—and was not worried that everything wasn't a straight path but one that encouraged exploring thoughts and imagination," fostering a sense "of belonging." They mentioned looking back with gratitude for the reflection circles, where they shared "thoughts and feelings in a kind and caring, nonjudgmental space," helping them learn to be more emotionally self-aware. [Relates to RQ2 and RQ4]

Across written reflections, conferences, and interviews, students expressed a strong sense of connection, frequently highlighting "the importance of ethics and empathy in design." They recognized how ethical design could prevent harm and increase positive impact. One student explained, "Being able to think about ethics and empathy while designing will get me closer to my goal of positively impacting people, as it will decrease the chances of creating things that could harm others." This insight reflects a key outcome of the course: the ability to adopt a design paradigm grounded in love, empathy, and ethics. [Relates to RQ2 and RQ3]

These findings suggest that although love may not initially resonate as central to engineering, sustained engagement with a relational curriculum—and the study and practice of love and its attributes—cultivates a more ethically aware and emotionally connected approach to design. Through transdisciplinary and relational methods, students began to explore the evolutionary, psychological, neuroscientific, and historical connections between love, empathy, compassion, and care—and between love and its attributes and technology—while recognizing the current disconnect between technological development and ethical responsibility. [Relates to RQ4]

One secondary student, reflecting on the philosophical implications of cell phone technology's impact on being human, wrote, "Questions that have spawned because of this experience mainly include the psychological effect and ethics surrounding the products we as engineers make." Another commented, "It [cell phone technology] has been built on a lack of ethical and empathetic designs, driving us further into this isolated world. The hope is that in the future... we can change the way that we deal with designs and create a more empathetic and ethical future of technology." [Relates to RQ2 and RQ3]

These broader insights point to the potential of relational pedagogies rooted in learning about love to promote both intellectual and emotional growth. This approach fosters psychological safety, supports vulnerability, and enhances peer collaboration. A second-year postsecondary student described applying these relational skills in team settings, saying they learned to "see differences as a strength within our group" and to "diffuse potentially hostile discussions when the group disagreed." Classroom observations corroborated these outcomes. During a pendulum clock project, secondary students reported using empathetic listening, writing, sketching, and dialogue to work through conflicting ideas in physics and design. [Relates to RQ3 and RQ4]

By centering love—and moving through emotional and cognitive empathy toward compassion and care—the pedagogy enables students to think critically, identify diverse needs, and navigate complex design challenges. Integrating the humanities, social sciences, and arts within this transdisciplinary approach supported students in becoming well-rounded and more ethically attuned. [Relates to RQ4]

For example, one secondary student, reflecting on an Emily Dickinson poem [110] in the context of 19th-century patriarchy, emphasized the importance of trust and the role of science in revealing systemic inequities. They described the balance between emotional insight and scientific reasoning as crucial to engineering, where both social dynamics and technical knowledge are deeply intertwined.

Another student, responding to Sherry Turkle's article "The Flight from Conversation" [134], discussed society's "overreliance on technology," noting how digital devices create addictive "purposes" that distract from being present and from finding meaning and connection. In a reflection on the *Tao Te Ching* [60], the student wrote, "Without the hole in [doorway into] the room, it would lack purpose and would be useless," using this image to distinguish between usefulness and benefit in design and highlighting the importance of thoughtfulness in thinking around absence and restraint in ethical engineering practice and technological development. [Relates to RQ2 and RQ3]

The theme of trust also emerged in a student's reflection on journalist Maria Ressa's assertion that "without facts, there is no truth, and without truth, there is no trust," as well as her statements on the impacts of digital media [135]. The student connected this idea to the negative impacts of social media and the role technology plays in shaping thought and perceptions of truth. They also emphasized the importance of considering the ethical impacts of what engineers design, drawing on a chapter from *Creativity, Inc.* [136], which emphasizes that, while honesty and candor in creative teams are difficult, they are essential for building trust and fostering innovation. These student insights underscore the relevance of trust, transparency, and truth in engineering teams and design outcomes, as well as the ethical issues surrounding the engineering of technological systems. [Relates to RQ3 and RQ4]

Ultimately, the synthesis and integration of diverse sources and perspectives helped students form meaningful connections between their personal experiences, societal understanding, and the ethical responsibilities of engineering. As one student wrote, "Thinking about ethics and empathy in design helps me aim for a positive impact, reducing the chance of harm in my engineering outcomes." Another student summed up the experience by saying, "This class has made me think about how I can use my career path as not just a fulfillment for me, but for the world around me." [Relates to RQ3 and RQ4]

Discussion

The conceptual framework guiding this investigation positions love, empathy, and ethics as central—rather than peripheral—to the study, practice, and pedagogy of engineering. This reframing of engineering as a relational, ethical, and emotionally attuned discipline is reflected in students' varied, and at times unsettled, responses. Across both secondary and postsecondary reflections, the results suggest that centering love as a conceptual and practical anchor—rather than treating it as an abstract ideal—can shift students' perceptions of engineering and its broader implications. The course activities did not merely present love as a topic for study and dialogue; they invited students to engage with it as a methodology—prompting reflection on interpersonal relationships and the application of ethical, empathetic reasoning and compassion in design work. This pedagogical approach aligns with the framework's emphasis on engineering as a space of interconnectedness, care, and shared responsibility.

The resistance and discomfort voiced by some students highlight the challenge of unsettling dominant narratives of engineering as purely technical or neutral—but also affirm the importance of this work. By encouraging vulnerability, relational awareness, and ethical engagement, the pedagogical approach implemented here embodies the conceptual framework in action, offering a compelling model for transforming engineering education.

This study explored how students in secondary and postsecondary engineering education settings made sense of love in engineering—including their unprompted associations with the concept, as well as their responses to activities that invited reflection on its presence, absence, or relevance. While some students expressed discomfort with the idea of love in engineering, many embraced it when given the opportunity. This aligns with recent research suggesting that students can engage with emotional and ethical complexity in engineering when prompted [137]–[139]. Importantly, students' understandings of love were not superficial. They reflected on its psychology and on the internal negotiations involved in being in community with others and in caring. These findings support calls from scholars who argue that a love-informed pedagogy should be central to engineering education [138], [140]–[142]. While these scholars advocate for pedagogical approaches informed by love, care, and justice, the present study offers a unique perspective by examining how students explicitly engage in both the study and practice of love—as a methodological and reflective process—within their engineering education, influences multiple aspects of their personal and academic lives.

Qualitative evidence suggests that students conceptualized love through frameworks resonating with feminist, ecological, Indigenous, decolonial, and philosophical theories [17], [19], [33], [143], [144]. These insights indicate that students can think about love in ways that extend beyond romantic, technical, and human-centered understandings. This raises important questions for further research, such as: What factors facilitate or hinder students' ability to recognize and articulate their understanding of love? How might social and cultural contexts shape the way love is explored in engineering classrooms? How can this understanding extend our moral values to nature, both individually and societally, through design thinking, fostering respect for and a deeper connection to the environment and ecology?

The study also notes the influence of upfront transdisciplinary knowledge on interpersonal relationships and teamwork, though the mechanisms behind these transformations were not fully analyzed. Additionally, the research relies on coursework, observation, self-reported data, conferences, interviews, and surveys—each of which carries inherent subjectivity and potential for bias. This is particularly relevant when exploring how concepts like love, empathy, and ethics influence interpersonal relationships, teamwork, and conflict resolution in group design projects, as well as how students perceive their roles within the engineering field. The study does not definitively conclude whether the holistic pedagogy leads to a deeper understanding of self or more profound purposes, especially in traditional classroom environments.

The scope of this research—focused on secondary and postsecondary students within specific pedagogical contexts—limits its generalizability. While it highlights effective strategies, such as the early introduction of transdisciplinary knowledge, reflective practices, experiential learning, neurobiological models of learning, and small learning communities, there is limited evidence on how these approaches might be scaled or adapted across diverse educational settings. This is especially relevant when considering how students' attitudes toward engineering shift in different environments and how practices like self-love and relational self-awareness may evolve in more traditional settings. Addressing these gaps could strengthen the case for integrating relational and emotional dimensions into engineering curricula.

Pedagogical practices, such as individualized weekly student conferences, show promise but depend on emotional and cognitive attunement to each student's needs. Building trust within a supportive mentoring environment was crucial to students' success, though individual differences complicate objective assessment. The impact of a digital-free classroom, with a focus on analog practices, showed remarkable promise, particularly in reflective practices, self-awareness, and cognitive and emotional engagement. However, questions remain about the broader applicability of this pedagogy, including the need for more dedicated design courses, limitations posed by large class sizes, and the economic feasibility of implementing this holistic, transdisciplinary approach at scale.

While the primary focus of this study was not to evaluate instructional strategies in isolation, the findings highlight how the course's pedagogical design—particularly its emphasis on relationality, compassion, and emotional engagement—shaped students' perceptions and experiences. Activities like reflection and dialogue created space for students to consider love in relation to the world and engineering practice, even when they initially felt uncertain or resistant.

These practices fostered trust, vulnerability, and curiosity, suggesting that pedagogy plays a critical role in shaping how students interpret concepts like love, self-love, empathy, and ethics. These findings contribute to ongoing conversations about justice-oriented, relational learning environments in engineering education, suggesting that providing students directly with transdisciplinary educational content on love may deepen their engagement with the social, ethical, and emotional dimensions of engineering while emphasizing the importance of building community and fostering openness in teaching practices.

It is also worth noting that students in this study connected love to a range of themes, including engineering, technology, psychology, neuroscience, attachment, addiction, ethics, empathy, compassion, care, communication, the environment, justice, teamwork, and relationships. These associations suggest that love could serve as a generative entry point for students to reflect on their identities, values, and responsibilities. Future research could explore how this pedagogy intersects with existing ethics and design curricula or investigate its potential to influence students' personal growth, professional values, and broader social consciousness, particularly in relation to ecology as a whole.

Conclusions

This study underscores the potential of focusing student learning on the study and practice of love and its associated attributes, including ethics, within engineering education. It shifts the discipline from its traditional emphasis on technical neutrality to one that embraces relational, emotional, and ethical dimensions. By reconceptualizing engineering as a transdisciplinary practice rooted in care, interconnectedness, and shared responsibility, the research highlights how fostering the active practice of love—associated with vulnerability, relational awareness, and ethical engagement—can transform students' perceptions of the field and its societal role. The findings suggest that when love is framed as both a conceptual and practical anchor—rather than an abstract ideal—students engage more meaningfully with the complex challenges of engineering. These challenges include students contemplating the implications of emerging technologies—such as AI and robotics—that they may help create, and recognizing that if ethical consequences are not considered prior to development, the responsibility for managing these implications often shifts to an unprepared society, particularly regarding questions of moral agency and operational control.

The impact of emerging technologies that engineering students must confront includes critical questions about how we preserve our individuality in an increasingly homogenized technological landscape. What are the implications of these shifts on an individual's sense of purpose and their capacity to contribute meaningfully to the world? How do complex technological systems complicate our ability to engage with reality and challenge societal power structures, particularly as we become increasingly consumed by the need to respond to machines? Moreover, how can we sustain care and attention for natural ecologies as interconnected technologies, designed to capture human attention, accelerate the pace of change?

This paper raises broader philosophical questions about the role of education, advocating for the integration of works and dialogues that examine the ethical, emotional, and relational dimensions of technology. Drawing from the humanities, social sciences, and arts, students in engineering can benefit from transdisciplinary knowledge that encourages them to critically reflect on how the systems they create might prioritize subjective realities over objective ones. As technology becomes more immersive, it blurs the line between reality and simulation, fostering escapism and detachment from the immediate, tangible world. As we distance ourselves from empathy and responsibility for our actions, how does this impact our ethical obligations? What aspects of humanity might be lost as we merge further with machines? Finally, what role has love played in technological development, and what can we learn from its historical significance in shaping human progress?

These issues extend beyond design, prompting deep reflection on creativity, humanity, and our shared responsibilities. Engineering curricula must confront the ethical dilemma of compelling children to adapt to technologies that may harm not only their psychology but also their sense of humanity. While technology undeniably offers significant advantages, its rapid adoption often leaves vulnerable populations with the stark choice of either adapting or being excluded from the social order. This paper focuses on education—particularly engineering education—as a key means of addressing this dilemma. What are we truly teaching the next generation, and how are we preparing them for a future that is evolving at an unprecedented pace? As technological advancements consistently outpace ethical reasoning, how can we recalibrate this imbalance? Could the teaching of love within engineering education serve as a catalyst for this necessary shift?

Technology seeks to connect us in ways that evoke feelings of affirmation, appreciation, and care—qualities traditionally associated with love. But is this connection truly genuine? And, if it is, are we fully aware that through our technologies, we may be redefining what it means to be human in ways that earlier, less complex technologies did not? How much emotional labor are we willing to delegate to technology? These are critical questions that engineering students must grapple with. Understanding neuroscience, psychology, and the historical impact of technology on culture and power structures is essential. The philosophy of what it means to be human requires knowledge across multiple disciplines, making it vital to approach these issues from a transdisciplinary perspective. As technology becomes ubiquitous, its impact on humanity intensifies, making it increasingly inescapable. Could a holistic view help us extend moral values to nature, countering the dominant, technology-driven vision of a homogeneous human existence?

Ongoing exploration of these questions—and the ways in which transdisciplinary knowledge, particularly love and ethical reasoning, can be placed at the forefront of engineering education—may open new avenues for shifting design paradigms. What forms of knowledge are necessary to balance human values with technical solutions? These shifts could help preserve a more holistic understanding of what it means to be human, in harmony with nature and our broader ecological systems, while also addressing the complexities of the technological systems we create. By transcending traditional educational boundaries, we may cultivate an engineering mindset rooted in relational, ethical, and ecological awareness.

References

[1] I. Barbour, *Ethics in an Age of Technology*, vol. 2, The Gifford Lectures. London: SCM Press, 1992.

[2] M. Heidegger, "The Question Concerning Technology," in *The Question Concerning Technology and Other Essays*. New York: Harper & Row, 1993.

[3] S. Moran, *Ethical Ripples of Creativity and Innovation*. London: Palgrave Macmillan, 2016.

[4] J. W. Moore, Ed., *Anthropocene or Capitalocene?: Nature, History, and the Crisis of Capitalism*. PM Press, 2016.

[5] National Research Council, *Engineering Education: Designing an Adaptive System*. Washington, D.C.: National Academies Press, 1995.

[6] J. Tonn and A. Hira, "Engineering as Conflict: A Framing for Liberal Engineering Education," Paper presented at the 2024 ASEE Annual Conference & Exposition, Portland, Oregon, June 2024, doi: 10.18260/1-2--47271.

[7] D. Graeber and D. Wengrow, *The Dawn of Everything: A New History of Humanity*. Picador, 2021.

[8] R. W. Kimmerer, *Braiding Sweetgrass: Indigenous Wisdom, Scientific Knowledge, and the Teachings of Plants*. Minneapolis, MN, USA: Milkweed Editions, 2013.

[9] E. A. Povinelli, *Between Gaia and Ground: Four Axioms of Existence*. Durham, NC: Duke University Press, 2021.

[10] H. Jazaieri, "Compassionate education from preschool to graduate school: Bringing a culture of compassion into the classroom," *Journal of Research in Innovative Teaching & Learning*, vol. 11, no. 1, pp. 22–66, 2018.

[11] J. C.-H. Cheng and M. C. Monroe, "Connection to nature: Children's affective attitude toward nature," *Environment and Behavior*, vol. 44, no. 1, pp. 31–49, 2012.

[12] M. C. Nussbaum, *Upheavals of Thought: The Intelligence of Emotions*. Cambridge, UK: Cambridge University Press, 2001.

[13] V. Held, *The Ethics of Care: Personal, Political, and Global*. Oxford, UK: Oxford University Press, 2006.

[14] T. Singer and O. Klimecki, "Empathy and compassion," *Current Biology*, vol. 24, no. 18, pp. R875–R878, Sep. 2014.

[15] M. L. Hoffman, *Empathy and Moral Development: Implications for Caring and Justice*. Cambridge, UK: Cambridge University Press, 2000.

[16] J. C. Tronto, *Moral Boundaries: A Political Argument for an Ethic of Care*. New York, NY: Routledge, 1993.

[17] b. hooks, *All About Love: New Visions*. New York, NY, USA: William Morrow, 2000.

[18] T. Metz, *Meaning in Life: An Analytic Study*. Oxford, U.K.: Oxford Univ. Press, 2013.

[19] D. Abram, *The Spell of the Sensuous: Perception and Language in a More-Than-Human*. Vintage, Feb. 25, 1997.

[20] M. Povinelli, "A longitudinal engineering education study of a holistic engineering pedagogy and holistic design thinking methodology on postsecondary student academic success and retention," in *Proc. 2023 ASEE Annu. Conf. & Expo*., Baltimore, MD, USA, Jun. 2023. [Online]. Available: https://doi.org/10.18260/1-2--42416

[21] P. Freire, *Pedagogy of the Oppressed*, Bloomsbury, 1970.

[22] B. Tehranineshat et al., "Compassionate care in healthcare systems: a systematic review," *J. Natl. Med. Assoc*., vol. 111, no. 5, pp. 546-554, 2019.

[23] G. Barton and S. Garvis, "Theorizing compassion and empathy in educational contexts: what are compassion and empathy and why are they important?," in *Compassion and Empathy in Educational Contexts*, pp. 3-14, 2019.

[24] A. Velasquez et al., "Developing caring relationships in schools: A review of the research on caring and nurturing pedagogies," *Rev. Educ*., vol. 1, no. 2, pp. 162-190, 2013.

[25] J. E. Zull, *The Art of Changing the Brain: Enriching Teaching by Exploring the Biology of Learning*. Sterling, VA, USA: Stylus Publishing, 2002.

[26] J. L. Hess and N. D. Fila, "The development and growth of empathy among engineering students," *American Society for Engineering Education*, 2016.

[27] M. J. Povinelli and J. A. Robinson, “Integrating design thinking into an experiential learning course for freshman engineering students,” in *Proc. 2018 ASEE Annu. Conf. & Expo*., Salt Lake City, UT, USA, Jun. 2018, pp. 1–21. [Online]. Available: https://doi.org/10.18260/1-2--30681

[28] C. C. Cruz, "Brazilian grassroots engineering: A decolonial approach to engineering education," *Eur. J. Eng. Educ*., vol. 46, no. 5, pp. 690–706, 2021.

[29] P. Ekman, "An argument for basic emotions," *Cognition & Emotion*, vol. 6, no. 3-4, pp. 169-200, 1992.

[30] M. J. Povinelli, “A transdisciplinary knowledge approach using a holistic design thinking methodology for engineering education,” in *Proc. 2024 ASEE Annu. Conf. & Expo*., Portland, OR, USA, Jun. 2024. [Online]. Available: https://doi.org/10.18260/1-2--46503

[31] S. Nyholm, *This is Technology Ethics*. Hoboken, NJ, USA: John Wiley & Sons, 2023.

[32] A. Clark, *Natural-Born Cyborgs: Minds, Technologies, and the Future of Human Intelligence*. Oxford, UK: Oxford University Press, 2003.

[33] D. Haraway, “A cyborg manifesto: Science, technology, and socialist-feminism in the late twentieth century,” in Simians, *Cyborgs and Women: The Reinvention of Nature*. New York: Routledge, 1991, pp. 149–181.

[34] H. Simon, *The Sciences of the Artificial*, 1st ed. Cambridge, MA: MIT Press, 1969.

[35] D. J. Siegel, *The Developing Mind: How Relationships and the Brain Interact to Shape Who We Are*. New York, NY, USA: Guilford Publications, 2020.

[36] P. J. Richerson and M. H. Christiansen, Eds., *Cultural Evolution: Society, Technology, Language, and Religion*. London: Penguin, 2013.

[37] C. Camerer, G. Loewenstein, and D. Prelec, "Neuroeconomics: How neuroscience can inform economics," *Journal of Economic Literature*, vol. 43, no. 1, pp. 9–64, 2005.

[38] J. LeDoux, *The Deep History of Ourselves: The Four-Billion-Year Story of How We Got Conscious Brains*. New York, NY, USA: Viking, 2019.

[39] R. Wright, *The Moral Animal: Why We Are the Way We Are—The New Science of Evolutionary Psychology*. New York, NY, USA: Pantheon Books, 1994.

[40] F. de Waal, *The Age of Empathy: Nature’s Lessons for a Kinder Society*. New York, NY, USA: Harmony Books, 2009.

[41] M. Mangalam et al., "On the psychological origins of tool use," *Neuroscience & Biobehavioral Reviews*, vol. 134, p. 104521, 2022.

[42] G. M. Slavich, "Social safety theory: a biologically based evolutionary perspective on life stress, health, and behavior," *Annual Review of Clinical Psychology*, vol. 16, no. 1, pp. 265–295, 2020.

[43] M. A. Hofer, "Early social relationships: A psychobiologist's view," *Child Development*, pp. 633–647, 1987.

[44] C. Chen, R. M. Martínez, and Y. Cheng, "The developmental origins of the social brain: empathy, morality, and justice," *Frontiers in Psychology*, vol. 9, p. 2584, 2018.

[45] J. Decety, "The neuroevolution of empathy," *Annals of the New York Academy of Sciences*, vol. 1231, no. 1, pp. 35–45, 2011.

[46] S. D. Preston, "The origins of altruism in offspring care," *Psychological Bulletin*, vol. 139, no. 6, p. 1305, 2013.

[47] A. A. Marsh, "Neural, cognitive, and evolutionary foundations of human altruism," Wiley *Interdisciplinary Reviews: Cognitive Science*, vol. 7, no. 1, pp. 59–71, 2016.

[48] L. K. Ma, R. J. Tunney, and E. Ferguson, "Does gratitude enhance prosociality?: A meta-analytic review," *Psychological Bulletin*, vol. 143, no. 6, p. 601, 2017.

[49] R. L. Baskerville et al., "Genres of Inquiry in Design-Science Research: Justification and Evaluation of Knowledge Production," *MIS Quarterly*, vol. 39, no. 3, pp. 541–564, 2015.

[50] M. Morriss-Kay, "The evolution of human artistic creativity," *J. Anat.*, vol. 216, no. 2, pp. 158–176, Feb. 2010, doi: 10.1111/j.1469-7580.2009.01160.x.

[51] M. Lombard and P. Gärdenfors, "Causal cognition and theory of mind in evolutionary cognitive archaeology," *Biological Theory*, vol. 18, no. 4, pp. 234–252, 2023.

[52] I. Kant, *Critique of Pure Reason*, M. Weigelt, Ed., Trans., and Intro., and M. Muller, Trans. London, U.K.: Penguin Classics, 2008.

[53] E. L. MacLean, "Unraveling the evolution of uniquely human cognition," *Proc. Natl. Acad. Sci*. U. S. A., vol. 113, no. 23, pp. 6348-6354, Jun. 2016.

[54] P. J. Richerson and M. H. Christiansen, Eds., *Cultural Evolution: Society, Technology, Language, and Religion*. London: Penguin, 2013.

[55] R. C. Solomon and K. M. Higgins, Eds., *The Philosophy of (Erotic) Love*. Lawrence, KS, USA: University Press of Kansas, 1991.

[56] S. May, *Love: A History*. New Haven, CT, USA: Yale University Press, 2011.

[57] A. Smuts and C. Grau, Eds., *The Oxford Handbook of Philosophy of Love*. Oxford, U.K.: Oxford Univ. Press, 2024.

[58] W. Shakespeare, *The Complete Works (The Oxford Shakespeare)*. New York: Oxford University Press, 1965.

[59] *Bhagavad Gītā*, trans. E. Easwaran. Tomales, CA, USA: Nilgiri Press, 2007.

[60] T. Lao, *Tao Te Ching*, G.-F. Feng and J. English, Translators. New York, NY, USA: Vintage Books, a division of Random House, 1972.

[61] J. Assante, *The Erotic Reliefs of Ancient Mesopotamia*. New York, NY, USA: Columbia University, 2000.

[62] R. B. Parkinson, *Reading Ancient Egyptian Poetry: Among Other Histories*. Hoboken, NJ, USA: John Wiley & Sons, 2009.

[63] R. Feldman, "The neurobiology of mammalian parenting and the biosocial context of human caregiving," *Hormones and Behavior*, vol. 77, pp. 3–17, 2016.

[64] P. Gilbert, "The evolution and social dynamics of compassion," *Social and Personality Psychology Compass*, vol. 9, no. 6, pp. 239–254, 2015.

[65] T. Singer and O. M. Klimecki, "Empathy and compassion," *Current Biology*, vol. 24, no. 18, pp. R875–R878, 2014.

[66] B. Fehr, C. Harasymchuk, and S. Sprecher, "Compassionate love in romantic relationships: A review and some new findings," *Journal of Social and Personal Relationships*, vol. 31, no. 5, pp. 575–600, 2014.

[67] N. Eisenberg and J. Strayer, Eds., *Empathy and Its Development*. Cambridge, UK: Cambridge University Press, 1987.

[68] R. W. Levenson and A. M. Ruef, "Empathy: A physiological substrate," *Journal of Personality and Social Psychology*, vol. 63, no. 2, pp. 234–246, 1992.

[69] M. Davis, *Empathy: A Social Psychological Approach*. Boulder, CO, USA: Westview Press, 1996.

[70] A. Smith, "Cognitive empathy and emotional empathy in human behavior and evolution," *The Psychological Record*, vol. 56, pp. 3–21, 2006.

[71] S. D. Hodges and M. W. Myers, "Empathy," in R. F. Baumeister and K. D. Vohs, Eds., *Encyclopedia of Social Psychology*. Thousand Oaks, CA, USA: Sage, pp. 296–298, 2007.

[72] J. Decety et al., "A neurobehavioral evolutionary perspective on the mechanisms underlying empathy," *Progress in Neurobiology*, vol. 98, no. 1, pp. 38–48, 2012.

[73] J. Decety, "The neural pathways, development and functions of empathy," *Current Opinion in Behavioral Sciences*, vol. 3, pp. 1–6, 2015.

[74] I. Bretherton, "The origins of attachment theory: John Bowlby and Mary Ainsworth," in *Attachment Theory*, 1st ed., New York, NY: Routledge, 2013, pp. 45-84.

[75] D. Richo, *How to be an Adult in Relationships*. Boston, MA: Shambhala Publications, Inc., 2002.

[76] J. Dewey, *Experience and Education*. New York, NY, USA: Kappa Delta Pi, 1938.

[77] E. H. Erikson, *Identity: Youth and Crisis*. New York: W. W. Norton, 1968.

[78] A. H. Maslow, *Motivation and Personality*, 3rd ed. New York, NY, USA: Harper & Row, 1987.

[79] R. M. Ryan and E. L. Deci, *Self-Determination Theory: Basic Psychological Needs in Motivation, Development, and Wellness*. New York: Guilford Press, 2017.

[80] E. Fromm, *The Art of Loving*. New York: Harper & Row, 1956.

[81] D. W. Winnicott, *Playing and Reality*. London, U.K.: Tavistock, 1971.

[82] D. W. Winnicott, *The Maturational Processes and the Facilitating Environment: Studies in the Theory of Emotional Development.* London, U.K.: Hogarth Press, 1965.

[83] A. N. Schore, *Affect Regulation and the Origin of the Self: The Neurobiology of Emotional Development*. Hillsdale, NJ, USA: Lawrence Erlbaum Associates, 1994.

[84] P. Fonagy, G. Gergely, E. Jurist, and M. *Target, Affect Regulation, Mentalization, and the Development of the Self*. New York, NY, USA: Other Press, 2002.

[85] B. Brown, *The Gifts of Imperfection: Let Go of Who You Think You're Supposed to Be and Embrace Who You Are*. Center City, MN, USA: Hazelden Publishing, 2010.

[86] L. G. Underwood, “Compassionate love: A framework for research,” in *The Science of Compassionate Love: Theory and Research*, B. Fehr, S. Sprecher, and L. G. Underwood, Eds. Malden, MA, USA: Wiley-Blackwell, 2009, pp. 3–25.

[87] O. François et al., "The Pedagogue, the Engineer, and the Friend," *Human Nature: An Interdisciplinary Biosocial Perspective*, vol. 31, no. 4, pp. 462–482, 2020.

[88] P. Chödrön, *Awakening Loving-Kindness*. Boulder: Shambhala, 2017.

[89] E. Easwaran, trans., *The Dhammapada*. Tomales, CA, USA: Nilgiri Press, 2007.

[90] J. LeDoux and N. D. Daw, “Surviving threats: neural circuit and computational implications of a new taxonomy of defensive behavior," *Nat. Rev. Neurosci*., vol. 19, pp. 269-282, Apr. 2018.

[91] J. L. Goetz, D. Keltner, and E. Simon-Thomas, "Compassion: an evolutionary analysis and empirical review," *Psychological Bulletin*, vol. 136, no. 3, p. 351, 2010.

[92] S. Pinker, *How the Mind Works*. New York: W. W. Norton & Company, 1997.

[93] E. Blevis, "Sustainable interaction design: invention & disposal, renewal & reuse," in *Proc. SIGCHI Conf. Human Factors in Computing Systems*, 2007, pp. 503–512.

[94] P. Jacob and M. Jeannerod, *Ways of Seeing: The Scope and Limits of Visual Cognition*. Oxford: Oxford University Press, 2003.

[95] R. Louv, *Last Child in the Woods*. Chapel Hill, NC: Algonquin Books, 2005.

[96] J. Burke, *Connections*. Boston, MA, USA: Little, Brown and Co., 1978.

[97] J. Burke, "The Legacy of Science," in *The Impact of Science on Society*, NASA SP-482, NASA Langley Research Center, 1985.

[98] R. Clarke et al., "More-than-human participation: Design for sustainable smart city futures," *Interactions*, vol. 26, no. 3, pp. 60–63, 2019.

[99] E. Giaccardi and J. Redström, “Technology and More-Than-Human Design,” *Design Issues*, vol. 36, no. 4, pp. 33-44, 2020.

[100] J. J. Bryson, "Robots should be slaves," in *Close Engagements with Artificial Companions*, Y. Wilks, Ed. Amsterdam: John Benjamins Publishing Company, 2010, pp. 63–74.

[101] I. Persson and J. Savulescu, *Unfit for the Future: The Need for Moral Enhancement*. Oxford, U.K.: Oxford Univ. Press, 2012.

[102] I. Hartogsohn and A. Vudka, "Technology and addiction: what drugs can teach us about digital media," *Transcultural Psychiatry*, vol. 60, no. 4, pp. 651-661, 2023.

[103] C. Monet, *Monet: The Ultimate Impressionist*, S. Roe, Ed. New York, NY: Prestel, 2000

[104] J. J. Audubon, *Birds of America*. London, U.K.: Published by the author, 1827–1838.

[105] J. Muir, *My First Summer in the Sierra*. Boston, MA: Houghton Mifflin, 1911.

[106] H. D. Thoreau, *Walden; or, Life in the Woods*. Boston, MA: Ticknor and Fields, 1854.

[107] R. Carson, *Silent Spring*. Boston, MA: Houghton Mifflin, 1962.

[108] E. O. Wilson, *The Diversity of Life*. Cambridge, MA: Harvard Univ. Press, 1992.

[109] W. Wordsworth, *Selected Poems*. London, U.K.: Penguin Classics, 2004.

[110] E. Dickinson, *The Complete Poems of Emily Dickinson*, T. H. Johnson, Ed. Boston, MA: Little, Brown, 1960.

[111] W. Whitman, *Leaves of Grass*. Brooklyn, NY: Self-published, 1855.

[112] R. Benjamin, *Race After Technology: Abolitionist Tools for the New Jim Code*. Cambridge, UK: Polity Press, 2019.

[113] S. Turkle, *Alone Together*. New York, NY, USA: Basic Books, 2011.

[114] S. Federici, *Caliban and the Witch: Women, the Body and Primitive Accumulation*. Brooklyn, NY: Autonomedia, 2004.

[115] M. Puig de la Bellacasa, *Matters of Care: Speculative Ethics in More than Human Worlds*. Minneapolis, MN: Univ. of Minnesota Press, 2017.

[116] L. Winner, *The Whale and the Reactor: A Search for Limits in an Age of High Technology*. Chicago, IL: Univ. of Chicago Press, 1986.

[117] L. Suchman, *Human-Machine Reconfigurations: Plans and Situated Actions*, 2nd ed. Cambridge, UK: Cambridge Univ. Press, 2007.

[118] S. Zuboff, *The Age of Surveillance Capitalism: The Fight for a Human Future at the New Frontier of Power*. New York, NY: PublicAffairs, 2019.

[119] B.-C. Han, *Psychopolitics: Neoliberalism and the New Technologies of Power*. London, UK: Verso, 2017.

[120] N. Rose, Neuro: *The New Brain Sciences and the Management of the Mind*. Princeton, NJ: Princeton Univ. Press, 2010.

[121] T. Mitchell, *Rule of Experts: Egypt, Techno-Politics, Modernity*. Berkeley, CA: Univ. of California Press, 2002.

[122] M. L. Hoffman, "The Contribution of Empathy to Justice and Moral Judgment," in *Empathy and Its Development*, N. Eisenberg and J. Strayer, Eds. Cambridge, U.K.: Cambridge University Press, 1987, pp. 47–80.

[123] D. Riley, "Ethics in engineering education: A view from the USA," *European Journal of Engineering Education*, vol. 33, no. 2, pp. 235–243, 2008.

[124] J. E. Arnold, "Creative Engineering," Creative Engineering Laboratory, Mechanical Engineering Department, Massachusetts Institute of Technology, 1955.

[125] R. H. McKim, "Designing for the Whole Man," presented at Special Lecturer Stanford University, 1959.

[126] X. Tang, “From 'Empathic Design' to 'Empathic Engineering': Toward a Genealogy of Empathy in Engineering Education,” in *Proc. 2018 ASEE Annual Conference & Exposition*, 2018.

[127] C. B. Zoltowski, W. C. Oakes, and M. E. Cardella, "Students' ways of experiencing human-centered design," *Journal of Engineering Education*, vol. 101, no. 1, pp. 28–59, 2012.

[128] J. A. Leydens et al., "Qualitative methods used in the assessment of engineering education," *Journal of Engineering Education*, pp. 65–72, 2004.

[129] J. Piaget, *The Origins of Intelligence in Children*. New York, NY, USA: International Universities Press, 1952.

[130] D. A. Kolb, *Experiential Learning Experience as the Source of Learning and Development*, 2nd ed., Pearson Education, Inc., 2012.

[131] C. Ellison, *Ethics and Aesthetics in Intelligent Design: A Relational Perspective*. London, U.K.: Routledge, 2017.

[132] S. S. Tomkins, *Affect Imagery Consciousness: The Positive Affects*, vol. 1, ch. 9. New York: Springer, 1962.

[133] T. Lewis et al., *A General Theory of Love*. New York, NY, USA: Vintage, 2001.

[134] S. Turkle, "The flight from conversation," *The New York Times*, 21 Apr. 2012. [Online]. Available: https://www.nytimes.com/2012/04/22/opinion/sunday/the-flight-from-conversation.html.

[135] M. Ressa, "Nobel Peace Prize winner Maria Ressa on press freedom," *PBS NewsHour*, 10 Dec. 2021. [Online]. Available: https://www.pbs.org/newshour/show/nobel-peace-prize-winner-maria-ressa-on-press-freedom.

[136] E. Catmull and A. Wallace, *Creativity, Inc.: Overcoming the Unseen Forces That Stand in the Way of True Inspiration*. New York: Random House, 2014.

[137] E. Loh, N. Toft-Nielsen, M. Dyvik, and D. Wilson-Lopez, “Beyond rationality: Reimagining the engineering student through emotions and identity,” *J. Eng. Educ.*, vol. 112, no. 2, pp. 267–285, Apr. 2023.

[138] D. Riley, “Engineering and Social Justice,” *Synth. Lect. Eng. Technol*. Soc., vol. 3, no. 1, pp. 1–152, 2008.

[139] D. Wilson-Lopez, R. Mejia, and D. Hasbun, “Latinx adolescents’ engineering design talk in small groups: Implications for equity and inclusion,” J. *Eng. Educ.*, vol. 105, no. 2, pp. 218–243, Apr. 2016.

[140] J. González-Pérez, M. Ríos-Angulo, and J. García-García, “Feminist technoscience and love as a principle for designing inclusive technologies,” *Int. J. Gend. Sci. Technol*., vol. 12, no. 2, pp. 193–212, 2020.

[141] J. Leydens and J. Lucena, *Engineering Justice: Transforming Engineering Education and Practice*. Hoboken, NJ, USA: Wiley-IEEE Press, 2018.

[142] A. Pawley, “Engineering education and engineering identity: Gender, culture, and epistemological development,” in *The Routledge Handbook of the Philosophy of Engineering*, D. Michelfelder and N. Doorn, Eds., New York: Routledge, 2021, pp. 246–256.

[143] A. Ahmed, *The Cultural Politics of Emotion*, 2nd ed., Edinburgh: Edinburgh University Press, 2014.

[144] J. Harjo, *Weaving Sundown in a Scarlet Light*. New York, NY, USA: W.W. Norton & Company, 2022.

Appendix A: Author Positionality Statement

As a male author, my identity as a parent, educator, engineer, artist, and poet deeply shapes my approach to exploring love and its ethical attributes in engineering design education. With a Ph.D. in Electrical and Computer Engineering and over thirty years of experience across technical and educational domains, I offer a perspective that bridges scientific rigor and humanistic insight.

My professional background includes roles in research, design, and management within aerospace defense companies, as well as collaborations with universities and government research labs, refining my understanding of engineering's broader societal impacts. Through my work as a practicing engineer, I have come to believe that education should nurture not only technical expertise and learner self-agency but also social-emotional intelligence—empathy, ethical reasoning, and a commitment to justice in its social, economic, and environmental dimensions.

This belief guides my teaching philosophy, which draws on constructivist and experiential learning theories, neurobiological models of learning, and affect theory to foster holistic, transdisciplinary pedagogies. My experiences as an educator and researcher at both secondary and postsecondary levels have enabled me to develop and implement curricula that integrate these values. Additionally, my work in environmental education, teaching nature skills, and serving as a nature center director has deepened my appreciation of human entwinement with ecosystems. Combined with my background in theology and the influence of family and community, these experiences have reinforced my understanding of the relational and ethical dimensions of love, compassion, and care—for both humans and the more-than-human world.

My practices as an artist and poet have reinforced my commitment to fostering student engagement with introspection and self-reflection, essential tools for intentional and embodied learning. These tools support critical, causal, creative, and visual thinking—often reinforced through analog methods, as well as critical reading and writing skills.

Drawing on my experiences teaching and mentoring students and early-career engineers, I support their intellectual, emotional, and ethical growth, advocating for a paradigm shift in engineering education that centers on transdisciplinary knowledge, holism, and love in design. This shift places these values at the heart of student learning, particularly in response to urgent ecological and societal challenges. The methodologies presented in this paper reflect this perspective, emphasizing the need for an engineering curriculum focused on the exploration and practice of love—its qualities such as self-love, empathy, compassion, and care—as a foundation for ethical reasoning and design thinking.