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Redefining Engineering: Love, Ethics, and Technology in a More-Than-Human World

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Introduction

Engineering operates globally as a dominant sociotechnical and epistemic system, producing, circulating, and legitimizing knowledge and power. Power, in this context, is relational: it emerges from the creation of knowledge, the transformation of matter and biotic life into energy, technologies, weapons, and economic value; and the deployment of these systems to organize, constrain, and control human and nonhuman relations. Engineering methodologies that rely on extraction from the environment for the benefit of humans have typically been zero-sum gains, operating through nonequilibrium, unstable processes. While these processes generate intended and unintended consequences, technology ethics often arrive only after ecosystem imbalances and catastrophic ruptures in ecological, cultural, and psychological relations have already occurred [1].

In this paper, 'other-than-human' and 'more-than-human' refer to all entities within ecological systems, apart from human or human-created technologies (unless otherwise noted). Further, ecology is not treated as external to human systems, but as the generative matrix within which human life and technological practices coevolved. At times, I use ecological to refer specifically to more-than-human systems; this distinction is analytical rather than ontological.

This analysis examines how engineering education reproduces power, tracing the historical, ecological, and philosophical dimensions of engineering's development. While building on reformist critiques of neutrality and instrumentalism in engineering education—which emphasize social responsibility, critical reflection, and sociotechnical awareness [2], [3]—this paper argues that these approaches remain largely within a framework that preserves engineering as fundamentally oriented toward technological production and human-centered social reform. In contrast, the present work advances a deeper ontological and epistemic reconfiguration in which engineering education is grounded in coevolutionary principles—defined later as *evoecolontology*. Within this framework, love's full dimensionality operates as a co-constitutive epistemic condition that structures relational knowledge formation and is actively cultivated as foundational within engineering education. This includes relationality with the more-than-human, transdisciplinary knowledge, and evolutionary understandings of co-emergent human–nature design, thereby reframing the discipline as foundational inquiry aimed at restoring equilibrium with more-than-human futures rather than primarily production-oriented practice.

To frame this argument, the next sections situate engineering within theories of knowledge and power, examining how the discipline itself generates authority through its epistemologies, design logics, and material practices across ecological, social, and technological contexts. While

Foucault, in *The History of Sexuality: An Introduction, Volume I* [4], characterizes biopower as the means by which nation-states control populations (regulation of life through knowledge and power), this paper argues that engineering itself constitutes a source of such power, generating authority through its specialized knowledge and technologies that can then be utilized by the state or other actors as a form of control. Uncertainty and change are interchangeable: engineering knowledge is constituted through the management of uncertainty, and engineering power arises through the creation of change. While this distinction between engineering power and biopower may be negligible if the state governs all technological realization, it becomes critical in cases where it does not. In such cases, it becomes necessary to examine how engineering exercises its authority through the organization of knowledge, operational logics, material processes, and attendant claims to neutrality.

Although sociotechnical scholarship examines the social dimensions of technology, it rarely considers how engineering education and the discipline reproduce extractive, human-centered paradigms while overlooking evolutionary and ecological perspectives [5], [6]. This paper examines how engineering's evolutionary, historical, philosophical, and ecological entanglements within capitalist imperatives and technological accumulation function as sources of legitimized power. Western ontologies grounded in categorical separations between living and non-living entities have long justified exploitation, positioning certain humans as superior while reducing the more-than-human world to a resource [7], [8].

These ontologies continue to inform engineering design and education, constraining capacities for love, deliberation, and creativity. As Heidegger argues in *The Question Concerning Technology*, which examines both the instrumental and anthropological dimensions of modern technology, technology is a means to an end and shapes how humans perceive and engage with the world [9]. While Heidegger's phenomenological critique illuminates how “enframing” conceals Being, it cannot account for the evolutionary-ontological dimension this paper advances—that enframing's relational counterpart, love's entwinement, co-emerged with engineering cognition as a constitutive species trait, and that its recovery through education is not only possible but necessary. Modern technological paradigms do not stand outside ecological relations, but increasingly abstract, mediate, or obscure them, producing the appearance of separation rather than its actuality. Extending this dual lens through evolutionary and ecological perspectives reveals that technology originally developed in capacities entwined with love, ethics, and other-than-human relations; however, as technological systems scaled, specialized, and became institutionally organized, they increasingly abstracted human activity from direct ecological and relational feedback, producing a consequential epistemic separation between humans and relational–ethical dimensions.

From an evolutionary–ecological perspective, engineering and technology were not merely technical skills but relational knowledge traits coevolving with human capacities for love, empathy, care, compassion, and ethical reasoning, while remaining interwoven with other-than-human systems. While technology once emerged in concert with these capacities, contemporary engineering practices increasingly render nature as "standing-reserve" [9], outpacing ethical reflection [10]. This framing, reinforced by Cartesian dualism [11], continues to shape how engineering education structures knowledge, ethical engagement, and the production of technological power.

To navigate these conceptual entanglements, this paper proposes an *evo-ecolontology* (hereafter evoecolontology) framework—defined as the ontological and epistemic reorientation of engineering toward relational, coevolutionary, and ecological principles grounded in love's relationality. This framework is rooted in *evoecolocentrism*: an evolutionary and ecological predisposition in which early technological engagement was inherently entwined with the coevolution of love and ethics as constitutive relational traits of humans in nature. In this view, technology, love, and ethics co-emerged as a holistic relational system, rather than as sequential or separable domains. In this work, I refer to the interconnected dynamics of love, ethics, and technology as *love's entwinement*. Engineering operates not only as a global sociotechnical system but—through evolutionary and ecological time—as an *eco-sociotechnical* (hereafter ecosociotechnical) one. The term ecosociotechnical emphasizes that ecological systems are not external 'impacts' of technology but integral to how technological knowledge and power are produced, circulated, and constrained—humans did not emerge from sociotechnical systems but from other-than-human ecological relations, within which tool-making and technological practices first developed through interactions with both abiotic and biotic systems—where ecosociotechnical describes this relational structure and evoecolocentrism names the evolutionary predisposition of the agents within it. The paper adds to the existing ecocentric literature—which repudiates human-centeredness in favor of ecological-centered perspectives [12], [13]—by highlighting an original dualism of ecological relationism inherent in early human development, in which other-than-human entities are recognized as both mortal and immortal, through the coevolutionary traits of love's entwinement. Critically, it centers responsibility, technology ethics, and the need for the discipline to critique itself and its educational practices, challenging the deterministic paradigm of technological advancement and the favoring of human-technology relationships over human and more-than-human ones.

By privileging technical rigor, efficiency, and human-centered problem solving, engineering curricula reproduce systemic patterns that marginalize ethical, relational, ecological, and political–economic dimensions. As Bateson observes in *Steps to an Ecology of Mind* [14], these patterns produce epistemological errors with disproportionate social and ecological consequences. Separation from ecological feedback—once integral to adaptive and relational decision-making—generates cascading errors in engineered change and uncertainty, while narrow disciplinary boundaries constrain the development of relational capacities, transdisciplinary knowledge, and philosophical inquiry. Students are trained to create and manipulate technological power without critically examining its consequences or their responsibility for producing it [15]. Structural features of engineering education—lectures, testing, and hierarchical pedagogies—further reinforce control over intimate understanding, perpetuating a human-centered paradigm in which technological change, power, and knowledge accumulate beyond human capacity to govern [16].

A central question this work addresses—how love and relational–ethical capacities might reconstitute engineering's epistemologies and educational foundations within a more-than-human world—demands a radical reorientation of the discipline. Focusing education on love, ecological accountability, and ethical reasoning—not as supplements to technical skill but as foundational to it—enables students to recognize how technological momentum in design produces harm. Effective pedagogy treats evolutionary, ecological, historical, philosophical, social, and psychological perspectives as foundational, fostering critical reflection on how engineering practices entangle with interrelated ecological systems, capitalist imperatives, and social hierarchies. By centering love and relational accountability, education can develop the capacity to resist extractive practices, honor more-than-human systems, and engage responsibly with knowledge and technological power.

The stakes are existential: contemporary technologies—artificial intelligence (AI), social media, algorithmic logistics networks, autonomous weapon systems, and extractive energy infrastructures—augment, control, and often supplant human relational and ethical capacities. They reveal the limits of instrumental ethics—whose claim to neutrality conceals harm already embedded in design—and of anthropologically informed and human-centered design, constrained by human perception, ego, and ethically unbalanced ambition, demonstrating the need for evoecolontological grounding. It is critical for engineering education to foster a pause in technological development—not only to repair ecological harm or counter capitalist extraction, but to interrogate how design produces harm across ecological, social, and relational dimensions. Such a shift could position engineering students, educators, and the discipline as stewards of both social and ecological systems, capable of pausing design, reflecting, and refusing action when technological momentum threatens ecological, social, and relational harm. Education has the power to shift the discipline from object-making to foundational inquiry and evoecolocentric interdependence in managing uncertainty.

Building on the author's previous work [17], [20], it was demonstrated that love and its capacities—empathy, compassion, concern, and care—together with ethical reasoning, when enacted through relational action, can form the core of student relational learning in curricula. Hereafter, this constellation is called *love and its relational–ethical capacities*. Rather than being merely anthropocentric, love shapes feelings, thoughts, and actions as expressions of relational–ethical capacities, extending human engagement to the ecological through nature and biophilia [18], [19]. This pedagogy [17], [20] cultivates relational understanding and the practice of love, shaping students' sense of self, relationships, and design within the other-than-human world, while recasting both engineering education and the discipline as an ecological restorative practice rather than treating ethics as a peripheral add-on.

Using coevolution as a conceptual lens, this analysis examines how these capacities emerged alongside early technological practices and how ethical failures in human and other-than-human relations critique the discipline and its educational foundations. The concept of evoecolontology emerged from an examination of what governs human capacities for design and technological development, informed by lifelong engagement with nature and thirty years of engineering and education experience amid deepening cultural, psychological, and ecological crises.

From this foundation, holistic engineering education calls for meaningful engagement with the ecological and social knowledge systems, the humanities, and the arts—not merely integrating perspectives from different fields, but reshaping how knowledge is framed, how problems are questioned, and how design responsibility is understood. When relationality, ethics, and ecological consequences are treated as peripheral rather than constitutive, it structurally reproduces technocratic and adjacent forms of power—epistemic, technological, institutional, political, and socio-ecological—instead of cultivating ethical reasoning toward other-than-human. Framed within a liberal education perspective, the humanities and social sciences are necessary epistemic correctives that enable engineering to function as an ethically responsive, ecologically and socially situated practice, cultivating students' judgment to refuse design when it would cause harm to other-than-human and humans [20]. For researchers, this implies a paradigm shift in curricula design, centering love and its relational–ethical capacities toward the more-than-human, moving beyond human-centered pedagogies.

The paper proceeds by tracing the evoecolontological rupture and the historical scaling of Σ(technology), before demonstrating how re-centering love and its relational–ethical capacities can transform engineering education and practice toward ecological and social equilibrium.

Engineering, Ecology, Technology, and the Problem of Power

Engineering's ecosociotechnical power relations are sustained, in part, by how engineering and its technologies are defined, taught, understood, and utilized—and by how technology ethics is framed within those relations. Heidegger posits that technology is hybrid: both a means to an end and a human activity—instrumental (ethically neutral in its causal function) and anthropological (ethically non-neutral, shaping perception and behavior) [9]. Heidegger argues that in ancient technology, this relationship remained embedded in craft and place; in modern technology, "Gestell" [9]—or enframing—transforms the world into standing-reserve, ordering everything as resources available for exploitation. Yet Heidegger's hybrid framework, taken alone, cannot account for the evoecolocentric predisposition through which technology and love's relational–ethical capacities originally coevolved as constitutive human traits. Crucially, what Heidegger leaves unexamined is how these extractive logics are institutionally reproduced through engineering education—the very site where they are normalized and made invisible. Moreover, Heidegger's concept of revealing remains itself anthropocentric—technology's unconcealment is measured through human perception alone, foreclosing the more-than-human relational awareness that evoecolontology demands.

In contrast, this paper advances an evolutionary–ecological predisposition theory of love's entwinement: the coevolution of human relational capacities and engineering cognition, through which early humans intentionally designed and used technologies within ecologically embedded relationships, enhancing adaptive survival. From this account, engineering emerges not merely as technological production but as an ontological mode of relational engagement, in which behavior is adaptive rather than deterministic and human agency operates flexibly through goal-directed learning and deliberation [21]. By treating stones as standing-reserve for tools from the very beginning, early humans reveal that enframing the world is an inherent species trait rather than a historical shift—and crucially, they entwined, not enframed, stones with love and its relational–ethical capacities. Technology ethics is thus simultaneously instrumental, anthropological, and evoecolontological: what Gestell has obscured is not a lost time of innocence but a foundational attunement—the disclosure of the more-than-human world as kin rather than just resource—that engineering education can recover.

Cartesian dualism, reinforced by Kantian and Smithian legacies [22], [23], enabled Gestell logics to supersede love's relational grounding—fracturing the foundational evolutionary–ecological structures of relational design engagement that this paper's evoecolontological reorientation of education seeks to recover. Consequently, within these engineered systems, humans themselves become resources of the technological non-living, subjected to the same instrumental logic applied to other-than-human entities. These technologies are materialized through biopower's biopolitical regimes [4]—AI algorithms, social media, data mining, and voter manipulation—and through geontopower's governance of the life–nonlife distinction under capitalist extraction [24], increasingly bypassing the relational and ethical capacities that evolved alongside humans and ecological systems, producing a profound rupture in more-than-human consciousness.

Heidegger describes thought as a "coming-into-the-nearness-of-distance," a form of "presencing" that can be interpreted as emerging in the relational spaces between cultures and their technological practices over time [25]. Yet technological practices extend beyond cultural usage, deriving their power from engineering cognition as shaped and transmitted through educational ontologies. Engineering presencing thus appears more as extimacy—exteriorized and revealed at a distance—than intimacy, leaving humans psychologically suspended between technological manifestations, increasingly absent of more-than-human and human-to-human relationality, as individual and social ambition aligns with technological momentum rather than ecological relationality. This dynamic is evident in contemporary AI algorithms that drive attention, influence decision-making, and supplant human and ecological relationships [10]—illustrating the evoecolontological constraint at the heart of this paper: when technological power supersedes love's ecological relationality, ethical reflection arrives too late to prevent harm.

Evoecolontological Rupture: From Original Dualism to Engineering Education

To understand the roots of the ethical and relational rupture in modern engineering, historical human engagements with other-than-human entities reveal what Heidegger's distinction between modern and ancient technology does not fully capture: the evoecolocentric relations of the original generative dualism of ecological relationism. Even prior to the Enlightenment, animals, materials, and tools were used as sources of energy and power; as far back as stone tool use, engineered technology conferred human influence and agency. Within this framework, humans recognized other-than-human entities—including life and non-life—as both mortal and immortal: sacred, with minds coinciding with yet distinct from our own, inspiring awe, reflection, usage, and respect [26], [27]. Technological engagement was inseparable from relational and ethical awareness, embedding humans within coevolutionary ecological networks. In the absence of direct relational engagement with nature, humans experience it as intimately void.

This attenuation of relational perception became cemented in Western thought and practice when Descartes reformulated the original dualism into an ontological framework that conceptualized animals and matter as mindless machines, while positioning humans as possessing body, mind, and soul [9]. Nature once held the secret of human origins, but humans no longer inhabit it.

Cartesian dualism abstracts and separates humans and their innate engineering cognition from nature, severing the relational and ethical balance that once embedded humans within ecological systems. Consequently, we have lost the perception of a Gestalt truth that once guided harmony between ecosystems and ourselves, leaving us in the fractured space between nature and accelerating engineered technological systems. Even within Western thought, from Aristotle's distinction between living and non-living entities, to Democritus's atomic theory, to Anaxagoras's view that even atoms possess a form of life [28], conceptualizing the non-living as inert and exploitable was historically contingent rather than inevitable.

Darwin's *The Expression of the Emotions in Man and Animals* anthropomorphized animals, interpreting their behaviors through a human lens [29], contributing to the marginalization of their distinct minds and powers. Engineering practices took advantage of these ontologies, treating nature—and Indigenous people—as raw material to build tools and technologies while eroding relational and ecological knowledge, exemplifying the enduring influence of dualistic and extractive frameworks in contemporary engineering [7]. Categorical thinking, while evolutionarily advantageous, conceals deeper relational truths within Western ontologies. Contemporary engineered systems reveal a species whose creation and use of technological knowledge and power has driven countless extinctions and imperiled ecological systems, both physically and spiritually. Engineering's framing of knowledge as power and control forecloses ethical reasoning toward the more-than-human. We construct our own realities because nature cannot speak clearly within the Cartesian dualist frame imposed by human thought.

Technology limits our distinctively human capacity for goal-directed deliberation, shaping how we perceive, experience, and act in consuming the world. Its sum now exceeds ecology, free will, imagination, and creativity. AI algorithms illustrate this shift, outperforming humans in strategic games (e.g., DeepMind's AlphaZero in chess), complex medical diagnostics, and creative domains such as language and illustration [30]–[32]. These systems reflect patterns encoded in human knowledge and cognition, while functioning both as co-design agents in design processes and in scientific research. By stunting imagination, crucial in the reasoning cycle of creativity and design, engineered technology undermines core human capacities. Instrumental and anthropological technological responses do not merely mediate existence—they increasingly foreclose the relational and adaptive capacities through which humans once navigated the world.

Enframing does not reside in the tool itself, but occurs through engineering practices that can disrupt its relational balance with nature, thereby preventing nature from revealing itself and, reciprocally, revealing us. As illustrated above, this paper identifies three interrelated engineered conditions through which the loss of an evoecolontological state arose: first, a departure from the original dualism of ecological relationism, in which nature was recognized as both instrumental and sacred—manifesting in extractive engineering practices; second, the psychological consequences of existential uncertainty manifested in cataclysmic weapons deployed at scales of mass death; and third, the rise of systems technologies that usurped human agency by mediating perception, decision-making, and relational awareness at speeds exceeding human cognitive and emotional capacity.

Our early evolutionary ancestry embedded emotional patterns in the psyche, and the emotional scar of losing this original duality—compounded by cascading technological effects—constrains relational moral imagination and design, producing disturbances in how we perceive relational consequences and find evoecolontological equilibrium with nature, ourselves, and society. Ethical frameworks that account for these evolutionary traits—how our brains operate "upon differences" [14]—should consider not only those differences, as Bateson describes, but also the limitations imposed by Western ontological perception, relational understanding, ecological connectedness, and both extrinsic and intrinsic biases. These embodied and emotional patterns are reinforced and institutionalized through engineering education, shaping how engineers are trained to perceive, value, and act upon the more-than-human world.

Engineering, Ecology, and the Reproduction of Technological Power

The affective and relational orientations shaped by these conditions do not arise in isolation; they are reproduced through engineering education, institutions, and practices, reinforcing ontological frameworks that perpetuate historical ruptures in our understanding of being. To understand how this reproduction operates, it is necessary to move beyond contemporary discourse and practice, which often frames engineering narrowly as the application of science and mathematics to problem solving [2], [33], prioritizing technical efficacy and human-centered goals at the expense of evoecolontological equilibrium. In contrast, this paper conceptualizes engineering as a cognitive and composite knowledge trait that evolved in Homo sapiens through observation and engagement with other-than-human relations, grounded in relational perception and affective attunement. This knowledge trait was supported by empirical attunement to predictable relational and causal patterns in nature, guided by emotion- and memory-linked intuition, and enabled by goal-directed deliberation [21].

Crucially, this trait emerged alongside love and its relational–ethical capacities, interwoven with design knowledge and technological development in early human history—necessarily entangling engineering with broader evoecolocentric questions of why and how it engages the more-than-human. Engineering cognition is thus universal to Homo sapiens—a constitutive trait of human being rather than a specialized professional capacity—making the discipline of engineering not the origin of this capacity but one historically contingent and increasingly narrow expression of it.

Technology is often defined as sociotechnical public knowledge of ‘how-to,’ oriented toward reproducible human purposes [34]. More fundamentally, however, technology is the materialization of engineered knowledge—transformed into tools, artifacts, and systems that operate within an ecosociotechnical space. While these artifacts can be referred to as technology, engineering denotes the evolutionarily emergent human cognitive–relational capacity that enables such transformations. As an evolutionary trait, engineering manifests through technology and combines reproducibility with a capacity to generate and scale functions across contexts.

Higher-order reasoning—including theory of mind and understanding unobservable causal mechanisms—allowed humans to develop distinctively human relational conceptions of objects such as weight and intention [35], [36]. A single object, such as a rock, may serve diverse purposes—cracking nuts, cutting wood, or inflicting harm—illustrating how engineered technological capacity often exceeds any singular intended use, through humans' causal understanding of unseen perceptual and relational patterns. When intentionally shaped into a tool, a rock becomes embedded in a knowledge–power dynamic oriented toward purpose, shaping individual, ecological, and social agency. Reproduced and varied, such tools become technologies that, through engineering cognition, intertwine with evolutionary processes—including natural selection and kin-network dynamics—shaping gene transmission [37]. Engineering's generative capacity—adaptive and evolutionarily grounded—can thus scale and diversify faster than the relational and ethical frameworks originally embedded in its practice, pulled forward by advances in manufacturing, mathematics, and science that progressively abstracted it from the ecological and ethical relationships that once guided its use.

Tool making was not only a means of ensuring offspring and kin survival, but a valued social capacity and a mode of relational, affective engagement with nature [38]. Over time, however, engineering practices increasingly prioritized accelerating technological production over these relational foundations, rupturing the evolutionary–ecological entwinement with love and ethical relationships that had historically balanced its application. The sections that follow trace how this rupture was scaled through the expansion of engineering knowledge and its institutionalization.

The Historical Scaling of Evoecolontology Rupture

Knowledge has always been a form of power, enabling humans to survive, organize, and adapt across diverse ecologies. Archaeological and anthropological evidence suggests that, especially from roughly 30,000 years ago, many human societies organized social and material practices through relational engagement with their ecologies, emphasizing reciprocity, responsiveness, and coexistence over extractive domination [39]. Over time, power became increasingly centralized as early states formed and political systems—through coercion, bureaucracy, or ruler authority—redefined governance, distancing it from ecological and communal interdependence [40]–[42]. Eventually, technological expansion exceeded the relational–ethical capacities that sustained the evoecolontological balance—enabling patronage, militarization, and patriarchal colonial structures to consolidate through engineering's production of goods, weaponry, and power.

Engineering emerged from this evolutionarily grounded cognitive–relational capacity, exemplified in Western history by figures like Leonardo da Vinci, who designed bridges, mechanisms, fortifications, and armaments for princely and state patrons [43]. It became closely intertwined with power, evolving into military engineering and shaping the ontologies, educational structures, and institutional practices of Western engineering [44]. This entwinement of engineering with state and military power generated the epistemic conditions under which extraction and the marginalization of nonhuman life and hierarchically differentiated human populations could be systematically justified [22], [45]. Certain humans were falsely positioned as uniquely endowed with higher-order reasoning, theory of mind, and moral authority. These hierarchies were sustained through intertwined power, economic, philosophical, and epistemic practices underpinning industrial, colonial, and extractive systems that reshaped social and ecological relations [4], [7], [22], [23], [45].

With the rise of industrial capitalism fueled by engineering, large-scale energy extraction—first from water, then coal, and later oil—reshaped human societies and ecological systems, embedding logics of control, productivity, consumption, and sovereignty into engineered, economic, and environmental relations [46], [47]. This engineering-driven trajectory created a profound imbalance: relational–ethical capacities in more-than-human systems were suppressed, allowing technical knowledge and industrial growth to advance beyond the constraints that had historically grounded them. As a result, the diversity of social systems and their ecological interrelations was diminished—setting the conditions under which engineering, capitalism, and state power would coevolve into mutually reinforcing systems of extraction and control.

This coevolution mutually reinforced extraction and control: engineering promoted disruption, efficiency, control, production, and consumption as moral goods, while capitalism and state power provided ideological cover—through narratives of 'innovation' and progress—for the extraction and commodification of nature and human labor. Today, these intertwined systems—including entrepreneurial capitalism, consumerism, and the military-industrial-academic complex—continue to reproduce capitalist-technological imperatives, exacerbating wealth disparity, concentrating control, homogenizing cultures, degrading ecosystems, commodifying humans, and severing connection from the more-than-human world.

This commodifying logic found concentrated expression in technologies, which continued to separate itself from earlier forms, such as stone tools, by developing properties that became—or were experienced as—necessities for daily social functions, such as communication interfaces and entertainment, while simultaneously cultivating addictive properties engineered to exploit the brain's neurochemical reward systems, eroding individual autonomy and undermining collective and societal agency over its use. In doing so, this advancement became both a product of and accelerant to humanity's disconnection from love's relational–ethical capacities and nature, propelling that logic to ultimately engulf all of humanity—dissolving even its privileged exemptions—and commodifying what it means to be human itself.

This relentless drive for technological advancement embodies an evoecolontological crisis: engineered systems—from colonial extractivism to AI algorithms to greenhouse-gas–emitting infrastructure—produce and reproduce Western ontological frameworks that recast ecological, relational, and ethical constraints as mere hindrances to progress, generating social orders and material conditions that routinely exceed human capacity to adjudicate or govern [7], [14], [24], [48]. Together, these forces deepen the evoecolontological rupture, manifesting in human psychological and cognitive processes, ethics, and educational practices—setting the stage for diagnosing how engineering perpetuates this disruption.

Diagnosing the Loss of Evoecolontology Equilibrium

These conditions have been diagnosed across multiple disciplinary lenses, including psychological transformation [49], ethical insufficiency [50], the structural excess of technics over human agency [51], and political arrangements embedded in technological artifacts [52]. This work argues that, at its core, the condition stems from engineering's disconnection from its evoecolontological capacities, a disconnection reproduced through education and practice.

To confront this condition, this paper turns a critical lens on engineering, foregrounding its limiting agency over technological proliferation and its accelerating trajectory toward harmful innovation. Engineering education is positioned as a key site where this estrangement from relational ethics with humans and the more-than-human is reproduced and potentially contested. Ethics—rooted in love and ecology—offers a counterforce to human-centered pressures and the systemic consequences of technological accumulation.

Contemporary epistemological framings privilege technical execution, often obscuring questions of origin, exclusion, and harm in design and knowledge production. Critical engagement with engineering's evoecolontological use of knowledge and power therefore involves not only intervention but also refusal—recognizing when not to act. This requires examining engineering's histories, assumptions, and developmental logics—alongside its ecological consequences and how it co-produces extractive social, economic, and ecological systems—recognizing that even neutral terms such as ‘shape’ can obscure processes of extraction, violence, and harm, including colonialism, pollution, extinction, and psychological damage.

By privileging technical problem-solving, efficiency, and economic gain, curricula reinforce logics that conflict with relational–ethical commitments, concealing engineering's embeddedness in extractive systems requiring ethical, ecological, and social accountability. This raises a central tension: whether engineering can respond to crises it has helped produced, whether curricula can be reoriented toward relational and transdisciplinary forms of knowing grounded in love, or whether more radical epistemic interventions are required.

How should engineering hold itself accountable for the knowledge and technological capacity it produces? Bateson observes that the desire for power corrupts, and those who seek it often rely on technological instruments provided by engineers to exert control [14]. This dynamic originates in engineering education and extends into formations such as biopower and geontopower, allowing engineering to evade full accountability. While engineers address technical means of power, ecological and social dimensions remain equally consequential. Power requires containment, distribution, an object to act upon, and a responsive field—principles that apply as much to ecological and relational power as to the physics of force. A central philosophical task of engineering could involve questioning ecological objects and responses in ways that do not privilege human centrism. These considerations include extractive practices, the extent of integration with AI, and the ways technologies are harnessed by capitalist oligarchs, states, or other actors to concentrate power. Could managing technological manifestations of power—and restoring evoecolontology equilibrium in a more-than-human world—constitute a new form of engineering ethics, one that places responsibility squarely on the engineers producing these technologies, particularly given the structural lag between technological production and ethical response?

Love and Ethics: Breaking Engineering’s Exclusion

Engineering drives ecological extinction, environmental collapse, wealth disparity, and loss of agency—producing systemic nonequilibrium and entropic consequences that constitute a crisis not merely environmental but ontological, exposing a fracture in how engineering understands being, love, responsibility, and interdependence within the more-than-human world. This fracture is sustained by the assumption that technical innovation alone is sufficient for problem-solving—an assumption reinforced psychologically through mastery and egocentrism at the expense of humility and care; culturally through human exceptionalism and systemic detachment; and epistemically through positivist framings that privilege quantification and control while erasing lived, moral, and ecological dimensions of knowledge [53], enabling solutions framed as beneficial to routinely externalize harm while claims of neutrality obscure ethical positioning.

This grounding in love is precisely what engineering's human-centered paradigm most fundamentally excludes. In previous work, the author [17] positioned love as a relational and ethical practice beyond personal emotion or romantic attachment—central to the human condition and expressed through cognitive, emotional, and behavioral dimensions that both shape and govern care, cooperation, and collective well-being across human and more-than-human relations. Its absence produces an imbalance between ego and relational orientation that generates systems exceeding ethical governance, reduces ethics to instrumentalism, and constrains engineering cognition within anthropocentric limits that prevent recognition of nonhuman agency and ecological significance. Love and its relational–ethical capacities are not peripheral values but evoecolocentric (evolutionary) conditions—grounded in a metaphysical relationality with nature—that shaped cognition, creativity, and moral reasoning.

Embedded in engineering education, love anchors how knowledge, power, and technological intervention are understood within more-than-human relations [17], [20]. These capacities deepen ecological awareness and enable ethical design refusal, as students recognize when proposed solutions risk harm to other-than-human entities, humans, or ecological systems. From a coevolutionary perspective, these capacities developed alongside early technological practices as constitutive relational traits [39], [54]—their marginalization in engineering as both discipline and profession represents not merely a pedagogical gap but an evolutionary rupture.

Engineering power, biopower, and geontopower operate through logics of knowledge production, control, and extraction; love interrupts these logics by re-centering accountability and expanding ethical concern beyond human-technology utility. As Foucault demonstrates, knowledge and power are inseparable [4]—meaning every design decision exercises power over human and more-than-human worlds, whether or not acknowledged. Three persistent engineering pedagogical deficiencies follow from this current analysis: failure to teach love and its relational–ethical capacities—including love's entwinement; reliance on human-centered ethical frameworks that cannot account for more-than-human harm; and marginalization of ecological consciousness and biophilia—the evolved affinity for living systems that once mediated human–environment balance and whose erosion engineering education has accelerated.

Correcting these deficiencies moves beyond biocentrism [12] or Naess's ecocentrism [55], bridging individual moral commitment and collective ethical practice by targeting the discipline of engineering itself. Flourishing requires cultivating love and embedding evoecolontological ethics in engineers, expressed through their technologies: prioritizing ecological needs over human-technology dominance, extending ethical value beyond the living, and recognizing obligations within more-than-human relations. Ethics is most effectively situated at its source—

engineering education—since responsibility cannot be displaced onto end users or AI agents, as technological systems actively shape behavior and constraint [56].

These deficiencies appear in contemporary practice, where evolved capacities for love and ethical reasoning are routinely bypassed. A Nobel laureate's reflection on developing DeepMind toward artificial general intelligence illustrates the ecological dimension: protein-folding AI extends human life while disregarding ecological balance, energy consumption, and displacement of expertise [57]. The race for neural implants illustrates the agency dimension: physiological risks such as brain tissue scarring [58] and broader concerns regarding privacy and ecological impact [59] are minimized as technological momentum overrides relational responsibility and ethical reflection—underscoring the need to cultivate these capacities in engineering education.

Attempts to address this pattern through design methodology have been made—the author introduced a “holistic design thinking” methodology connecting love, ethics, and engineering [20], and showed that transdisciplinary approaches grounded in love-based ethics cultivate relational accountability across ecological, social, and material systems [60]—yet the divide between ecological and technological reasoning remains unresolved. Western ontologies fragment love, design, ethics, and ecology, severing technological practice from ecological accountability; Indigenous and multicultural knowledge systems offer reciprocal, ecosociotechnical frameworks that Western engineering discourse has historically suppressed.

Consequently, engineering design imposes upon ecological and social realities while often concealing harm through claims of neutrality, reproducing systemic imbalance. Design grounded in evoecolontological awareness counters this concealment by establishing boundary conditions that minimize ecological harm, acknowledging that innovation exercises ego and power. This transformation begins with a deliberate pause in technological advancement—halting developments that perpetuate ecological damage or extractive logics and turning instead toward ethical reflection and ecological restoration. As Lao Tzu writes in the *Tao Te Ching*, "Returning to the source is stillness, which is the way of nature" [61]—engineering sometimes requires precisely this: pausing design in favor of stillness and reflection. Unlike discursive design practices, engineering produces material systems that entrench power asymmetries [62]; without this reorientation, engineering education will continue to reproduce the epistemological errors and systemic nonequilibrium that the following section examines—stakes that are structural, not merely philosophical, with life and death consequences.

Breaking the Paradigm of Engineering Education

Predominantly Western engineering education, constrained by social, economic, and institutional forces, typically changes incrementally and instrumentally, emphasizing technical skill and compliance. While historically effective within narrow parameters, these methods have long concealed significant costs. Reform efforts to enhance social responsibility often remain embedded in the same anthropocentric and capitalist frameworks, reproducing rather than disrupting systemic harm. Engineering, through its current methodologies, seeks to generate adaptive change in conditions of uncertainty, leveraging knowledge to guide action despite incomplete information [63]. This produces a paradox: engineering education accelerates technological capacity for change faster than ethical and relational reasoning can develop, enabling the transfer of control to external actors (human and AI) while engineering itself evades responsibility for downstream consequences.

Engineering education is the primary site through which these methodological orientations are transmitted and legitimized—making it both the source of the problem and the necessary location of its address. Dominant methodologies reveal internal anomalies—epistemic and ethical failures—driving ecological extinction, weapon system violence, psychological harm, loss of agency, disparity [55], [56], and persistent ethical dilemmas [3]. These outcomes signal not isolated failures of application, but systemic breakdowns in how engineering knowledge is conceived, taught, and enacted. This paper proposes reorienting engineering education around evoecolontology relational frameworks, reframing its purpose toward responsibly producing and mediating knowledge and power.

Engineering methodologies that extract from the environment for human benefit, as established earlier, typically function as zero-sum gains, operating through nonequilibrium, unstable processes. Over time, the cumulative effects of such extractive technological practices destabilize ecological, social, and relational systems. Conceptually, these cumulative effects can be represented as a cascading chain in which ecology is the ultimate casualty:

$$\text{humans} \rightarrow \text{extraction} \rightarrow \text{other-than-human} \rightarrow \text{tool} \rightarrow \text{technology} \rightarrow \text{ecology}$$

In heuristic terms, the summation of technology can be interpreted in quantitative relational terms:

$$\Sigma(\text{technology}) > \text{death} > \text{ecology} > \text{living and non-living systems} > \text{free will} > \text{reason, imagination, and creativity},$$

where '>' denotes both relative systemic impact and the potential for technological accumulation to exceed the absorptive and adaptive capacity of ecological and social systems, pushing them into nonequilibrium and cascading disorder.

Bateson's "pathology of epistemology" [14] describes the condition engineering education is most at risk of reproducing: a way of knowing so structurally narrow that its errors only become visible after the damage is done—and only then, through bitter experience, does organism–environment interdependence reveal itself. This pathology is sustained, in engineering, by the systematic neglect of feedback loops—the relational signals from ecological and social systems that would otherwise interrupt Σ(technology)'s accumulative trajectory. This is precisely the condition Heidegger's concept of enframing describes [9]—a mode of revealing so total that its own consequences become invisible within it. Without a way of revealing them, epistemological errors compound with each technological advance, underwriting ecological and social harm before ethical reasoning can respond. Bateson traces these errors to "habits of thought" [14]—inherited patterns of perception that, in losing what he calls "metaphorical totemism," severed the relational awareness that once embedded humans within ecological systems. In engineering education, these habits are not incidental; they are reproduced structurally, training each generation of engineers to perceive the more-than-human world as a resource problem space rather than a relational one—a perception and pedagogy reinforced by the technologies that preceded them. The consequence is a discipline that reinforces Σ(technology)'s trajectory through the structural absence of relational and ecological feedback—most critically, through a lack of love as foundational and the exclusion of the transdisciplinary knowledge that would otherwise make its costs visible and its harms correctable.

This transdisciplinary knowledge includes revisiting our evolutionary ancestry—moving beyond the Rousseau–Hobbes binary and acknowledging the genetic encoding of cooperation and competition [64], [65], [66]—to illuminate human potential for balance with nature, requiring students to draw on insights from the humanities, sociology, economics, ecology, biology, neuroscience, psychology, and physics to grasp life, death, and the holistic relationships among all entities—living and non-living—and their environments. Collectively, these conditions—epistemological, ontological, and relational—manifest across engineering education as compounding structural shortcomings: limited transdisciplinary engagement with psychological and philosophical inquiry; underdeveloped capacities for love, empathy, ethics, ecological consciousness, and character development; neglect of evolutionary and historical foundations of design and technological innovation from an ecosociotechnical perspective; limited recognition of ontologies that extend value beyond humans, including evoecolontologies; and the siloing of ecological and ethical responsibility within environmental engineering rather than permeating it across all disciplines [67].

A pedagogy grounded in love, accountability, and multiple ways of knowing—where ethical and ecological awareness are foundational—is required. Building on the author's prior work centering engineering education on love [17], [20], [60], this paper argues that the deepening ecological crisis and accelerating loss of human agency demand more radical measures, including reorienting design education to prevent harm to the more-than-human world and address systems of disparity. A central question for engineering education is how students can evaluate whether to engage in a design when the ecological and relational consciousness and knowledge needed to recognize its consequences for living and non-living systems remain untaught. Incorporating evolutionary–ecological, historical, philosophical, anthropological, ecosociotechnical, and economic perspectives cultivates ethical, ecological, and analytical understanding at a system level and enables students to grasp technology in its broader systemic context.

Framed by the guiding introductory question, students in the author's courses engage in dialogue on love and its ethical capacities in engineering design, examining whether current technologies enable or disable human agency and empathy within historical context, and reflecting on empathy for themselves, other people, and the more-than-human world. They often note that generational differences in technology and experiences of the natural world complicate identifying ethical boundaries, raising questions about which human capacities and relationships with nature may be lost, preserved, or transformed. This dialogue encourages reflection on how conventional ethical reasoning may be insufficient to determine what is lost or whether technological advancement has exceeded ethical limits. Students also practice ethical refusal and accountability, recognizing when a design could cause harm and considering broader ecological, social, and human consequences. As part of this process, students interrogate the Σ(technology) framework directly—examining how their use of technology or own design decisions contribute to or interrupt patterns of accumulation and systemic nonequilibrium.

This systemic interrogation extends to understanding the brain in both 'hardware' and 'software' dimensions: the same evolutionary substrates that enable love, empathy, ethical reasoning, and relational awareness are those most vulnerable to erosion by engineered systems designed without accountability to those capacities. Students explore this directly, examining research alongside their own experiences of being addicted to technology, needing it to navigate their social and educational worlds, expressing concern about how digital surveillance constrains their freedom, and yet simultaneously wanting to be freed from it. In this way, technology itself becomes a site of revelation—disclosing, through its grip on perception and agency, the depth of humanity's disconnection from nature and love's relational–ethical capacities. This revelation makes engagement with the concepts of free will, determinism, and technological control, alongside examination of how inherited systems shape outcomes for living and non-living entities, central—not peripheral—to evoecolontology reasoning. Exploring transhumanist ethics—extending the more-than-human to AI and machines [68]—and examining how technology can undermine social structures by reducing political engagement to low-stakes digital actions that erode agency [67] and require no authentic personal risk are essential components of engineering education. Education should cultivate ecological consciousness through non-anthropocentric engagement with land and materials [12]. As Bateson notes, this restores attention to feedback loops and systemic homeostasis [14], fostering awareness of interdependence and the capacity to resist extractive practices while honoring other-than-human.

By acknowledging its role in ecological and social disruption, engineering education can restructure toward evoecolontological equilibrium and away from human-centrism as its primary orientation. Students are encouraged to confront how engineering and technological innovation have contributed to destruction, death, ecological loss, and loss of agency—and through this reckoning, to recognize that ethical reasoning alone is insufficient: it is love, as an evolutionary and relational capacity, that can give empathy, compassion, concern, care, and ethical commitment their full relational force and redefine responsibility toward the more-than-human and human world.

At its core, engineering education succeeds when it cultivates students' capacities to know, feel, and enact accountability to the living and non-living worlds they affect. As Lao Tzu reflects, "Love the world as your own self; then you can truly care for all things" [61]—a formulation that speaks directly to evoecolontology's grounding in love as an evolutionary and ecological principle rather than a sentimental one. Guided learning, introspection, and self-reflection enable students to confront inherited engineered systems and their consequences for both living and non-living entities.

Although the existential crises produced through engineering cannot be undone, they demand an immediate, radical, and ethically reoriented response to love's entwinement—one that positions educators and students as stewards of ecological and social systems rather than mere producers of technology. How engineering education responds to Σ(technology) will determine whether the discipline reproduces epistemological error or reorients toward ecological homeostasis.

Conclusion

Altering our dystopian, technologically deterministic trajectory necessitates more than reformist adjustment in engineering education—it calls for a foundational ontological and epistemic shift, one the evoecolontology framework proposed here enables. As an ecosociotechnical system, engineering generates and legitimizes forms of power that exceed ecological, social, emotional, and ethical capacities for response—precisely because engineering curricula's historical drift and deliberate disciplinary consolidation away from relational-ecological foundations have progressively displaced and severed love's entwinement from technological knowledge and practice, destabilizing the evolutionary-ecological equilibrium.

Without relational understanding, transdisciplinary knowledge, and holistic reflection as foundational, prevailing engineering curricula structurally reinforce delayed ethical consideration until harm has already occurred. To shift this trajectory, engineering education should leverage philosophical inquiry: Why do engineering education and engineering perpetuate the digital commodification and subjugation of humans and the more-than-human? How does engineering justify what it extracts from the world—human, more-than-human, and non-living alike—to 'fill it up with,' and toward what ends? How might a relational-ethical framework counterbalance engineering's deterministic momentum toward privileging technical efficacy and capitalist imperatives over the very capacities from which it co-emerged? Such inquiry grounds ecosociotechnical awareness and evoecolontological reasoning in engineering education.

By tracing engineering's entanglement with extractive ontologies, Cartesian dualisms, and the historical consolidation of power, this argument demonstrates how modern engineering education reproduces epistemological errors that generate systemic nonequilibrium, eroding human capacities for deliberation, imagination, and care. Consequently, equations that describe the laws of nature and the technologies they produce have proved more immediate and compelling than the subtler, relational knowledge embedded in the natural world—precisely because engineering education has excised the evolutionary-ecological foundations from which that knowledge and technical capacity co-emerged. Ethics, when treated as an add-on or corrective mechanism, cannot adequately address these conditions because it arrives too late, operating within the same ontological frameworks that produced the harm. The result is a discipline capable of immense knowledge and technical power yet ungoverned by the relational understanding that love's entwinement demands.

The evoecolontology framework proposed here responds to this impasse by positioning love and its relational–ethical capacities within more-than-human worlds as a foundational principle for engineering knowledge and practice. This is not a sentimental appeal but an evolutionary and ecological claim: these capacities co-emerged alongside technological ones as survival traits enabling humans to navigate complex ecological systems. Reintegrating them into engineering education calls for a radical restructuring of curricula, pedagogy, and disciplinary self-understanding. Love and its relational–ethical capacities function as the discipline's most essential counter-force, keeping enframing's extractive philosophical logic—which Heidegger's own framework cannot escape—visible and contestable within engineering education and practice. Teaching engineering as a practice embedded within more-than-human systems—accountable to ecological feedback loops and capable of ethical refusal—restores the systemic homeostasis Bateson identifies as essential to resisting extractive practices and honoring relational awareness.

Such a reorientation demands a deliberate pause in technological momentum. Rather than accelerating innovation under the assumption that technical solutions will resolve the crises they produce, cultivating the capacity to interrogate when not to act, when to refuse design, and when to prioritize ecological restoration over production becomes the discipline's most underlying pedagogical task. This pause repositions engineering as a site of foundational inquiry—where love, power, knowledge, and ethics are examined together—rather than as a pipeline for unchecked technological accumulation.

Future research should directly address the equilibrium between responsibilities to more-than-human entities and the design of autonomous technologies, how transhumanist ambitions shape the aims and pedagogy of engineering education, and how engineering education might structurally reorient around relational-ecological foundations—interrogating curriculum design and pedagogical models that could make love foundational to engineering practice. Equally pressing is understanding how students themselves are already demanding this shift—through rejection of purely technical identities, engagement with climate justice, and resistance to digital commodification—and how these demands might accelerate reorientation.

The future of more-than-human worlds hinges on whether engineering can move beyond human-centered domination toward relational ontology—a shift from substance to evoecolontological interdependence in engineering knowledge and practice. Embedding love, ethics, ecological consciousness, and transdisciplinary understanding at the core of engineering education is the pedagogical route through which equilibrium with other-than-human worlds could begin to be restored. This shift does not promise resolution through new technologies; instead, it offers a pathway toward responsible stewardship—one where engineering's power is governed by relational knowledge and accountability rather than the mandates of efficiency, capital, progress, or control, and where ethics, grounded in love's entwinement, arrives not after catastrophic rupture but as the foundational condition of engineering itself.

References

[1] P.-P. Verbeek and O. Kudina, “Ethics from Within: Google Glass, the Collingridge Dilemma, and the Mediated Value of Privacy,” Science, Technology, and Human Values, vol. 44, no. 2, pp. 291–314, 2019.

[2] S. Johnston, A. Lee, and H. McGregor, “Engineering as Captive Discourse,” Techné: Research in Philosophy and Technology, vol. 1, no. 3–4, pp. 128–136, 1996, doi: 10.5840/techne199613/413.

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

[4] M. Foucault, *The History of Sexuality: An Introduction, Volume I*. New York, NY, USA: Vintage Books, 1990.

[5] E. A. Cech, "Culture of disengagement in engineering education?," Sci., Technol., & Human Values, vol. 39, no. 1, pp. 42–72, Jan. 2014.

[6] G. L. Downey, "What is engineering studies for? Dominant practices and scalable scholarship," Eng. Stud., vol. 1, no. 1, pp. 55–76, Mar. 2009.

[7] A. M. K. Peters, "American engineering and engineering education are settler colonial projects: Making visible the logic of possession," in Proc. ASEE Annu. Conf. Expo., 2025.

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

[9] M. Heidegger, "The question concerning technology," in The Question Concerning Technology and Other Essays. New York, NY, USA: Harper & Row, 1993.

[10] N. Schuster and S. Lazar, "Attention, moral skill, and algorithmic recommendation," Philosophical Studies, vol. 182, no. 1, pp. 159–184, 2025, doi: 10.1007/s11098-023-02083-6.

[11] R. Descartes, *Meditations on First Philosophy, 1641*. Translated by J. Cottingham. Cambridge, UK: Cambridge Univ. Press, 1996.

[12] A. Leopold, *A Sand County Almanac: And Sketches Here and There*. Oxford, UK: Oxford Univ. Press, 1949.

[13] A. Naess, "The deep ecology movement," in Deep Ecology for the 21st Century, G. Sessions, Ed. Boston, MA, USA: Shambhala, 1995, pp. 64–84.

[14] G. Bateson, *Steps to an Ecology of Mind*. Chicago, IL, USA: Univ. of Chicago Press, 2000.

[15] M. H. Wisnioski, "'Liberal Education Has Failed': Reading Like an Engineer in 1960s America," Technology and Culture, vol. 50, no. 4, pp. 753–782, 2009.

[16] P. Freire, *Pedagogy of the Oppressed*. New York, NY, USA: Continuum, 1970.

[17] M. J. Povinelli, "Love and Its Attributes as a Foundation for Student Learning in Engineering Education," in Proc. 2025 ASEE Annu. Conf. & Expo., Montreal, QC, Canada, June 2025. [Online]. Available: https://peer.asee.org/love-and-its-attributes-as-a-foundation-for-student-learning-in-engineering-education. doi: 10.18260/1-2--46487

[18] G. Barbiero and R. Berto, "Biophilia as evolutionary adaptation: an onto- and phylogenetic framework for biophilic design," Frontiers in Psychology, vol. 12, p. 700709, Jul. 2021.

[19] G. Cajete, Native Science: Natural Laws of Interdependence. Santa Fe, NM, USA: Clear Light Publishers, 2000.

[20] 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, June 2024. [Online]. Available: https://peer.asee.org/46503. doi: 10.18260/1-2--46503

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

[22] I. Kant, Groundwork for the Metaphysics of Morals, 3rd ed., M. Gregor, Ed. Cambridge, UK: Cambridge University Press, 1997.

[23] A. Smith, The Wealth of Nations, R. H. Campbell and A. S. Skinner, Eds. Oxford, UK: Oxford University Press, 1976.

[24] E. A. Povinelli, Geontologies: A Requiem to Late Liberalism. Durham, NC, USA: Duke University Press, 2016.

[25] M. Heidegger, *Discourse on Thinking*, J. M. Anderson and E. H. Freund, Trans. New York, NY, USA: Harper & Row, 1966.

[26] J. Berger, *About Looking*. London, UK: Writers and Readers, 1980.

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

[28] J. Barnes, The Presocratic Philosophers, 2nd ed., London, UK: Routledge, 1982.

[29] C. R. Darwin, The Expression of the Emotions in Man and Animals, 3rd ed. London, UK: John Murray, 1998.

[30] D. Silver et al., “Mastering the game of Go without human knowledge,” Nature, vol. 550, pp. 354–359, 2017.

[31] A. Esteva et al., “Dermatologist-level classification of skin cancer with deep neural networks,” Nature, vol. 542, no. 7639, pp. 115–118, Feb. 2017.

[32] K. F. Hubert, K. N. Awa, and D. L. Zabelina, “The current state of artificial intelligence generative language models is more creative than humans on divergent thinking tasks,” Sci. Rep., vol. 14, Art. no. 3440, Feb. 2024, doi: 10.1038/s41598-024-53303-w.

[33] R. W. Foley, R. Sinclair, and A. Dennis, “Exploring values and norms of engineering through responsible innovation and critiques of engineering cultures,” in Proc. 2021 ASEE Virtual Annual Conf. Content Access, Virtual Conference, Jul. 2021, pp. 1–23, doi: 10.18260/1-2--37167.

[34] H. Brooks, “Technology, evolution, and purpose,” Daedalus, vol. 109, no. 1, pp. 65–81, Winter 1980.

[35] D. J. Povinelli, World Without Weight: Perspectives on an Alien Mind. Oxford, UK: Oxford University Press, 2012.

[36] F. Osiurak, J. Navarro, and E. Reynaud, “How Our Cognition Shapes and Is Shaped by Technology: A Common Framework for Understanding Human Tool-Use Interactions in the Past, Present, and Future,” Front. Psychol., vol. 9, p. 293, Mar. 2018, doi: 10.3389/fpsyg.2018.00293

[37] C. Darwin, On the Origin of Species by Means of Natural Selection, or the Preservation of Favoured Races in the Struggle for Life. London, UK: John Murray, 1859.

[38] 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.

[39] D. Graeber and D. Wengrow, The Dawn of Everything: A New History of Humanity. New York, NY, USA: Farrar, Straus and Giroux, 2021.

[40] J. C. Scott, Against the Grain: A Deep History of the Earliest States. New Haven, CT, USA: Yale University Press, 2017.

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

[42] L. Mumford, Technics and Civilization. New York, NY, USA: Harcourt, Brace & World, 1934.

[43] L. Reti, The Unknown Leonardo. New York, NY, USA: McGraw-Hill, 1974.

[44] E. S. Ferguson, Engineering and the Mind's Eye. Cambridge, MA: MIT Press, 1992.

[45] A. Smith, The Theory of Moral Sentiments, D. D. Raphael and A. L. Macfie, Eds. Indianapolis, IN, USA: Liberty Fund, 1982.

[46] R. J. Gordon, The Rise of American Growth: The U.S. Standard of Living since the Civil War. Princeton, NJ, USA: Princeton University Press, 2016.

[47] T. Mitchell, Carbon Democracy: Political Power in the Age of Oil. London, U.K.: Verso, 2011.

[48] A. Malm, Fossil Capital: The Rise of Steam Power and the Roots of Global Warming. London, U.K.: Verso, 2016.

[49] S. Turkle, Alone Together: Why We Expect More from Technology and Less from Each Other. New York, NY, USA: Basic Books, 2011.

[50] J. Savulescu and I. Persson, “Moral enhancement, freedom, and the God machine,” Monist, vol. 95, no. 3, pp. 399–421, 2012.

[51] B. Stiegler, Technics and Time, 1: The Fault of Epimetheus, R. Beardsworth and G. Collins, Trans. Stanford, CA, USA: Stanford Univ. Press, 1998.

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

[53] H. Longino, Science as Social Knowledge, Princeton University Press, 1990.

[54] M. Tomasello, M. Carpenter, J. Call, T. Behne, and H. Moll, “Understanding and sharing intentions: The origins of cultural cognition,” Behav. Brain Sci., vol. 28, no. 5, pp. 675–691, 2005.

[55] A. Naess, *Ecology, Community and Lifestyle: Outline of an Ecosophy*. Cambridge, UK: Cambridge University Press, 1989

[56] N. Bertholet and J. A. Cunningham, “Information technology and addiction science: promises and challenges,” Addict Sci Clin Pract, vol. 16, Jan. 2021.

[57] G. Kohs and G. Krieg, The Thinking Game, film, 2024.

[58] T. D. Y. Kozai, "Brain tissue responses to neural implants impact signal sensitivity and intervention strategies," ACS Chem. Neurosci., vol. 6, no. 1, pp. 48–67, Jan. 2015.

[59] M. Ienca and R. Andorno, "Towards new human rights in the age of neuroscience and neurotechnology," Life Sci. Soc. Policy, vol. 13, no. 5, 2017.

[60] 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, doi: 10.18260/1-2--42416. Available: https://peer.asee.org/42416

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

[62] L. Jönsson, “Design practice as a discursive and interrogating performance,” in Nordes 13: Designing Resilience, 2019.

[63] B. V. Koen, Definition of the Engineering Method. Washington, DC, USA: American Society for Engineering Education, 1985.

[64] J.-J. Rousseau, The Social Contract, Translated by G. D. H. Cole. London, UK: J.M. Dent and Sons, 1923.

[65] T. Hobbes, Leviathan, Edited by J. C. A. Gaskin. Oxford, UK: Oxford University Press, 2008.

[66] H. Lee, M. J. Friedman, S. B. Kim, and S. Oh, "DNA regulatory element cooperation and competition in transcription," BMB Rep., vol. 57, no. 12, pp. 509–520, Dec. 2024. doi: 10.5483/BMBRep.2024-0069.

[67] N. Ghazian and C. J. Lortie, “A review of the roots of ecological engineering and its principles,” Journal of Ecological Engineering, vol. 25, no. 1, pp. 345–357, 2024.

[68] E. Giaccardi and J. Redström, “Technology and more-than-human design,” Design Issues, vol. 36, no. 4, pp. 33–44, 2020.