Contextualizing Technological Stewardship: Origins and Implications of an Approach to Responsible Tech Development

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The Multiplicity of "Stewardship"

Technological stewardship, or "tech stewardship," is a concept used by some engineering educators as part of strategies to encourage responsible technological development. In the context of Canadian engineering education, the most prominent use of this term is in the Tech Stewardship Practice Program (TSPP), an online course in which several thousand participants - largely undergraduate engineering students at Canadian universities – have enrolled since 2021 [1].

The TSPP positions the term "tech stewardship" as "professional identity, orientation, and practice" with the goal of "bend[ing] the arc of technology towards good," [2]. Although the program differentiates the term from other approaches to responsible technological development, understandings of, and approaches to technological stewardship are not the same across all contexts. Other engineering education programs and scholars present technological stewardship in close relation to concepts like social responsibility [3] or responsible innovation [4], or use the term to describe a process of pedagogical design for the engineering classroom, rather than a practice for engineers to engage in [5]. Within the TSPP itself, 'tech stewardship' is defined in relation to a set of behaviors. Different parts of the program and related publications describe tech stewardship as a mindset, a practice, and a contributor to cultural change within engineering [6]. However, the theoretical grounding of the concept, and its relationship to other ways of teaching and practicing engineering ethics or design, is not discussed within the TSPP itself, nor in its related materials.

The authors of this paper are members of a cross-institutional research team studying the effects of the TSPP on students' understandings of engineering responsibility [1]. As we began our project in January 2023, the multiple meanings of "tech stewardship" – and of "stewardship" itself – became apparent. We noticed the word "stewardship" in diverse contexts, including in scholarly literature, on the news, and on our garbage and recycling bins. We spent team meetings discussing the relationship between the "tech stewardship" of the TSPP and notions of stewardship in other contexts: religious, environmental, Indigenous, policy-based, and design-focused. How did the "tech stewardship" of the TSPP position engineers? What was its relationship to the engineering culture that the TSPP founders sought to change? Was it challenging the status quo, or reinforcing it? After two team members stumbled across a book produced by the National Council of the Churches of Christ in the United States, titled, *Teaching and Preaching Stewardship* [7], we decided that deeper inquiry into the concept of stewardship was a necessary part of our research.

Language, as Williams argues [8], is not a neutral medium for communication. Instead, words are powerful tools that change over time and carry cultural and historical meaning, shaping our practices, thinking, and interactions with the world. When navigating concepts such as technological stewardship, clear definitions enable us to critically engage with them

and to communicate our own ideas more effectively. Without a clear understanding of the history and contexts of technological stewardship, it can be challenging to make sense of its dynamic and evolving nature, and to engage in meaningful scholarship or critique of the concept. We argue that understanding the roots and contexts of the term, including its multiple intended purpose(s) and audience(s), is essential to realizing the potential of technological stewardship approaches in engineering education.

We find the TSPP – a program that aims to cultivate equitable, sustainable, and responsible approaches to design – to be a particularly important space for critical analysis. While the intentions of the program are laudable, it is necessary to move beyond intentionality and understand the implicit messages about equity, sustainability, and responsibility that the program communicates to participants. Without a critical understanding, we see a risk that the TSPP's framing of these concepts may unintentionally present a hidden curriculum that reflects harmful aspects of dominant North American STEM cultures, including heteropatriarchy and settler colonialism [9], [10].

This paper takes a first step towards such an understanding by identifying, describing, and analyzing definitions and practices of "stewardship" from different contexts. To accomplish this, we examine notions of "stewardship" in Christian religious scholarship, environmental governance, forest management, Indigenous scholarship and governance practices, and several instances of technology stewardship. We begin by providing the etymology of the word, followed by a brief overview of how authors in these different contexts situate and understand "stewardship." Then, we compare and discuss the different conceptualizations based on *what* is being stewarded, *where, why, who, and how*. In our larger research project, we will continue this work by analyzing the content of the TSPP itself, interviewing the TSPP creators to understand their motivations and perspectives, and conducting focus groups with students before, during, and after they complete the program.

Conceptualizations of Stewardship

The word origin and contemporary definition of stewardship comprise several meanings that manifest across different contexts. The origin of the word stewardship is Greek, from *oikonomia,* which is also the origin of the word "economics." *Oikos* is usually translated as "household" and *nemein* is translated as "management and dispensation" [11]. In ancient Greece, *oikonomia* referred to a household in the sense of a nuclear family unit. The first appearance of the word is found in a poem by Phocilides from the sixth century BC, wherein the writer advises his friends to marry a "good *oikonomos* [steward] who knows how to work" [12].

Today, 'stewardship' is defined generally in connection with care, management, or both. According to one dictionary definition, stewardship of something denotes the way in which a person "control[s] or take[s] care of it" [13]. As we will present in the following sub-sections, modern uses largely conform to this definition, but present different perspectives on whether stewardship is a skill, a practice, or a way of thinking; to what extent "care" and "control" are emphasized or may overlap; and who is responsible for stewarding. In the subsequent

sections, we present conceptualizations of stewardship in contexts from religious scholarship to technology policy, to demonstrate the range of understandings that exist in contemporary literature.

Christian Stewardship

The word *oikonomia* also appears in the Bible. Its first appearance is in the book of Ephesians, which shows the apostle Paul encouraging the residents of Ephesus, a city in what is now western Turkey, to convert to Christianity. The text describes Paul's 'stewardship' of the Ephesians through his work to bring about their religious conversion. In this context, 'stewardship' maintains the ancient Greek sense of household management, but re-envisions the household as one headed by a Christian God, managed by his apostles and other servants on Earth, and containing all of humanity [11]. 'Stewardship' therefore denotes a clearly hierarchical relationship between God and humanity, as well as between Christians and non-Christians on Earth. Some Christian scholars also argue that 'stewardship' and 'economics' are structurally and philosophically connected, since God gives humans the possibility of creating wealth [14]. Neufeld extends the hierarchical stewardship relationships between God and humans to the natural world as well, arguing that Christian stewardship views natural resources as God's creation that is intended for human use and creation of wealth [14].

In tandem with these hierarchical relationships, Christian stewardship emphasizes progress through the 'civilizing' actions of conversion and settlement. If nature is God's gift, and humans are stewards of the natural world with the responsibility to manage that gift through settlement, then 'stewardship' "by definition is a settlement term" [15, p. 67].

Planetary Stewardship

The term stewardship has also been widely used in the context of climate change and environmental protection, where humans are seen as responsible for taking care of the planet. In this context, proponents argue that the Anthropocene demands technological and political solutions for "planetary stewardship." In the Anthropocene, humans, individually and collectively, are no longer considered subject to the planet's environment, but a geological force, capable of altering the Earth's system at the planetary level [16]. Scholars see this new historical role of 'geological force' variously as a call for action to take care of the environment [17], a new geological epoch ready for taking a human-centered direction [18] where we can be the architects of Earths' systems [19], or a warning for us, humans, to reconsider our "supremacy complex" [20].

Due to the challenges of reaching international agreements on the deployment and control of climate engineering technologies [21], public and private organizations and institutions have started discussing rules, mechanisms, structures, and processes to inform responses to climate change from local to global levels; an initiative known as "Earth Systems Governance" (ESG) [22], [23]. A foundational, guiding principle of ESG is planetary stewardship [24], which emphasizes humans' responsible governance and active preservation of the natural world. Planetary stewardship calls for public and private institutions to proactively manage socio-ecological systems to keep Earth at a "Holocene-like state" [24] in which human well-being can be ensured. Critics of planetary stewardship argue that the approach embodies outdated, linear, hierarchical, and mechanistic understandings of human agency in natural

processes [22]. For Jenkins [23], “planetary stewardship” is problematic since it centers humans – “creature[s] so disruptive of earth's ecology” (p. 154) – as the agents who must transform ecological systems and reshape human life within them. From this standpoint, true planetary stewardship would focus on stewarding the idea of humanity and humans’ responsible actions towards the environment.

Given that humanity plays a God-like role in the Anthropocene and climate engineering, researchers have proposed including religious perspectives in discussions about planetary stewardship [22], [23]. They argue that religious perspectives can provide an alternative view of humanity’s relationship with the planet throughout history and bring interpretative scopes and moral frameworks to evaluate ESG practices. Boettcher [22] presents three different perspectives on the relationship between humans and the environment in planetary stewardship: The “Benevolent Dominator” perspective, in which humans are powerful actors with specific responsibilities that we enact through climate engineering; the “Responsible Steward” perspective, in which deliberate climate intervention can be one part of our duty to protect the planet for future generations; and the “Part of an Interconnected Whole” perspective, in which humans are just one of many interconnected species. In this third perspective, stewardship means humility and understanding of our relations with the planet and other living beings.

Forest Stewardship

While planetary stewardship serves as a guiding principle for ESG practices, a more practical approach to environmental stewardship is “forest stewardship.” Forest stewardship emerged as a response to predatory and unsustainable practices in the forestry industry, where forests are “continually reshaped through power-laden and ecologically relevant relationships among various people, trees, understory plants, animals, soils, insects, water flows, and more” [25, p. 142]. Forest stewardship proposes a more responsible and sustainable approach to forest management. One of its applications is a market-oriented approach where companies can be certified if they follow the responsible forest management standards and guidelines established by the Forest Stewardship Council (FSC) [26]. The FSC is an international non-profit organization that advocates for sustainable forestry. FSC certifies companies as “forest stewards” [27] when they demonstrate zero deforestation, protection of animals and plants, fair compensation for workers, and respect for local communities’ rights. As of 2019, the Canadian province of British Columbia was the region with the most forest stewards worldwide [28].

Stewardship in Indigenous Contexts

In a variety of Indigenous contexts from both literature and practice, the word stewardship refers to the generational knowledge of taking care of the land and community. This knowledge is expressed through practical skills such as hunting, trapping, and gathering, and through the values of responsibility and reciprocity. Stewardship in this context means to give back to nature all that nature gives to us and to take only what we need [29].

H. R. Anderson, one of the founding directors of the Native American Theological Association, noted that the communities he engaged with had an ethic of generosity that differed from the dominant culture. In the dominant culture, the status in community was

acquired by having; in Indigenous communities, status was acquired by giving and sharing [30]. This basic tenet is expressed in many Indigenous contexts, where stewardship is not based on private "property." "We are land", is a Cree worldview, meaning we are made of the same material matter of the world and the species that constitute it [31]. The earth gifts humans with resources needed to live; in turn, humans have a responsibility to act as stewards of the earth and all its living beings.

A similar understanding of stewardship is expressed through the governance policies of the Council of the Haida Nation (CHN), an Indigenous Nation based in Haida Gwaii, on the Northwest Pacific coast of Canada. The CHN has an organized and practical approach towards land and marine stewardship that is enacted through educational programs and management plans [32]. An example of land stewardship, the Cedar Stewardship Area Management Plan [33] provides a strategy for managing and preserving local cedar trees that have existed in the area for over 5,000 years and are endangered due ongoing industrial logging practices. An example of marine stewardship, the Marine Planning Program, offers expertise and technical support from professionals to the CHN to manage protected areas in Haida Gwaii [34]. In these examples, stewardship is a practice that aligns intention, local knowledge, and values with actions that prioritize land and community over resource extraction.

Stewardship in Canadian Biotechnology

Some of the earliest analysis of stewarding *technology* that we identified comes from the Canadian policy context. In a paper for the Office of Biotechnology at Health Canada, Capelli and Saner [35] surveyed uses of the concept of stewardship across different regulatory and governmental arenas in Canada, the United States, Europe, Australia, and New Zealand. While they found instances of stewardship in environmental, manufacturing, and broad regulatory contexts, they also identified "stewardship of technology" as a significant category, focusing their analysis on biotechnology in particular.

Within the biotechnology realm, Capelli and Saner show how the Canadian federal government has portrayed 'stewardship' as a means of protecting the public, both from potential health and safety consequences of scientific and technological development, and from prospective threats that such development may pose to Canadian values. Government offices and politicians identified legislation, regulation, and standards as the "stewardship instruments" that could enact this protection. Notably, 'stewardship' in this context is distinct from innovation: stewardship itself is not about creating new technologies, but rather about safeguarding the public from the effects of biotechnology innovation.

Capelli and Saner highlight the relationship between stewardship and innovation as a key issue associated with stewardship of technology across countries and technological fields. Finding an appropriate balance, they argue, between developing new technologies and creating or updating regulations is the central concern of stewardship of technology. In some national contexts, stewardship is part of the innovation process, while in other countries (such as Canada), stewardship and innovation are separate but related policy "pillars." Across all technological stewardship contexts surveyed in this report, stewardship is the responsibility of government. However, in a subsequent policy brief written by one of the same authors, the

conception of stewardship is expanded to include consultation processes and voluntary initiatives, which may be the responsibility of government, industry, consumer groups, or citizenry writ large [36].

Stewarding Technology for Communities

A foundational approach to the idea of technological stewardship in academic literature, and the first use of the term "technology steward" or "tech steward" that our search identified, comes from the book, *Digital Habitats: Stewarding Technology for Communities* [37]. The authors developed this work based on lead author Etienne Wenger's previous, widely cited scholarship on communities of practice [38]. Accordingly, they define the purpose of stewardship and the role of the steward in association with community. In their framing, a tech steward is a community member who pays attention to and seeks to influence the use, adaptation, and dissemination of technology within their community: an individual who "take(s) responsibility for a community's technology resources for a time" [37].

Tech stewards, for Wenger, White, and Smith, act in service of their community's needs. Because the authors understand community development and technological development as mutually influential, they present tech stewardship as a "natural outcome" of taking care of a community that is focused on learning and growth, as Wenger's communities of practice are. Through examples ranging from the World Café conversational methodology to rare blood diseases, Wenger et al. show how tech stewards develop, introduce, or encourage the use of (digital) technologies to advance their communities' goals.

While Wenger et al. hold that anyone can be a tech steward, they emphasize that in order for their work to be effective, stewards require both comprehensive knowledge about their community and sufficient technological understanding of the tool or platform being introduced or discussed. They emphasize the need to keep focused on the community's needs and avoid becoming too invested in the technology itself: technological approaches should be a simple as possible and should evolve as the community develops.

Tech Stewardship for Engineering Culture Change

Finally, the most significant descriptions of the Tech Stewardship Practice Program's approach to stewardship (outside of the TSPP itself), are found in two publications authored by some of the program's developers, all of whom have been a part of the Canadian-based Engineering Change Lab (ECL) [6], [39]. The authors ground their motivation for engaging in tech stewardship in new technological developments, which give rise to numerous "dystopian possibilities" [39]. The consequences of technological innovation, they argue, can be mitigated through careful design; however, large-scale capacity for such mitigation does not currently exist within the engineering community. Nevertheless, the TSPP founders see engineering professionals themselves, as well as others involved in technological design and development, as key actors in responsible technological development and as the primary audience for tech stewardship.

"Tech stewards" can be anyone who is involved in technological development, according to the ECL framing. However, while the importance of interdisciplinarity is emphasized in these

publications, the authors centre engineers. ‘Stewardship’ is portrayed as a set of skills and practices that can be voluntarily undertaken by individuals, groups, or companies, but also as a mindset that must be widely adopted within the engineering community to reach a cultural “tipping point” towards stewardship. In this conceptualization, ‘tech stewardship’ is a “value sensitive approach” to engineering design [6], which the ECL envisions as an integral part of future technological innovation once sufficient cultural change has occurred within engineering.

Dimensions of Stewardship

The conceptualizations described above span different contexts, motivations, and definitions of stewardship. In Table 1, we summarize these diverse understandings by characterizing them according to five dimensions: 1. the object of stewardship, or the quantity being stewarded (what); 2. the context in which stewardship takes place or is desired (where); 3. the rationale behind calls for stewardship (why); 4. the people or groups responsible for stewardship (who), and 5. the ways in which stewardship is enacted (how).

Table 1 – Comparison of Conceptualizations of Stewardship

	1.What is being stewarded?	**2.Context of stewardship**	**3.Rationale for stewardship**	**4.Who is responsible for stewardship?**	**5.How does stewardship happen?**
Planetary stewardship [23]	Idea of humanity	Climate engineering	Addressing the climate crisis by rethinking how we act towards the planet as we develop new technologies.	Humanity, engineers	Mindset: Revisiting our place and role as humans on the planet, and our relationship with technology.
Planetary stewardship [22]	Environment	Earth system governance, climate engineering	Shaping discussions about deliberate climate interventions as we develop new policies and technologies.	Policymakers	Mindset: Recognizing humanity as part of the planet and acting with care, balance, and humility; working through bottom up, situated, and participatory practice.
Forest stewardship [27]	Forests	Forest management	Protecting forests and maintaining forest health by improving how forests are managed.	Companies, government, forest managers.	Practice: Zero deforestation, fair wage and work environment, conservation instead of preservation, and community rights.
Native American stewardship [30]	The Created Order (Christian faith)	Native American communities in the United States	Rethinking how Native American Christians have a culture of giving that reflects on their stewardship practices.	Native American Christian communities	Mindset: Stewardship is about giving. All people should have housing, food, and clothes in the community. A culture of shared goods.
Biotechnology Stewardship [35]	Biotechnology	(Canadian) technology policy	Protecting health and environmental safety, protecting Canadian values as we develop new biotechnologies.	Government, policymakers	Policy: Protecting public safety and values through regulatory safeguards.

Tech stewardship [37]	Technology, community well-being	Communities of practice	Serving a community's evolving needs through technologies.	Specific community members ("tech stewards")	Practice: Understand the community; identify and balance polarities; select or build an appropriate technology; manage introduction, use, and end-of-life.
Tech stewardship [6]	Technology, engineering students' behaviours	(Canadian) engineering culture	Avoiding negative consequences of technological innovation by guiding design through behaviours and mindsets that can lead to sustainable and responsible outcomes.	Engineers	Mindset and Practice: Sensitivity to values, embedding ethics, sustainability, and EDI principles into engineering design and culture.

Themes and Tensions Across Conceptualizations of Stewardship

Some common themes emerged across conceptualizations of stewardship, most notably an association with care. While care was expressed in very different ways – from paternalistic and anthropocentric to reciprocal and ecocentric – and oriented towards different entities – from one's household to the planet to a specific community to technologies themselves – all the definitions we examined placed stewards in relationships of care with humans, beliefs, things, or ecosystems. Most conceptualizations also presented stewardship in the context of a shift in epistemology or worldview, even when stewardship itself was characterized as a specific process, policy, or set of skills. Stewardship rarely described the status quo, and generally represented an aspirational state of policy, practice, or being.

There were also several significant distinctions between definitions. One tension that we observed across different understandings of stewardship relates to the distribution of power and agency in stewardship relationships. Ancient Greek and Biblical stewardship concepts are strongly hierarchical, positioning the steward as either an all-powerful entity or the manager of a clearly subordinate quantity/group. Some framings of environmental stewardship, planet stewardship, and forest stewardship echo this hierarchical structure by placing humans firmly above other parts of the ecosystem in an anthropocentric worldview, granting them responsibility for either control or strictly managed care. In the Canadian biotechnology context, the government takes on the responsibility for protecting a subordinate public by exercising the stewardship tools at their disposal: laws, regulation, and standards. In contrast, other understandings of planetary stewardship and some Indigenous uses of stewardship view stewardship as a shared responsibility. In these contexts, the responsibility for stewardship is distributed throughout a community or across all of humanity. We are all responsible to each other and to the ecosystems in which we are embedded.

A related but distinct contrast concerns the difference between stewardship as protecting something that currently exists, and stewardship as growing, enhancing, or developing new things. This is most obvious in biotechnology policy discussions, where Capelli and Saner identify the relationship between stewardship and innovation as a key issue for policymakers. This also emerges in Wenger, White, and Smith's discussion of tech stewardship: while many of the examples they discuss involve developing new technologies, their vision of stewardship focuses squarely on serving the community and cautions prospective tech stewards against the risk of becoming distracted or swayed by technological innovations. The version of tech stewardship proposed by the ECL, in contrast, aims specifically at technological development, and couples stewardship with innovation in its intention of making engineering culture more inclusive, sustainable, and responsible.

The third significant tension that we noted was between stewardship that focuses on a specific community and its needs, as opposed to stewardship with a broader scope. Wenger, White, and Smith define tech stewardship in relation to communities of practice. A tech steward is responsible for and beholden to their own community and its needs, desires, and values. Anderson's view of stewardship in Indigenous contexts is similarly community-focused, even as it emphasizes relationality between all members of the natural world. Other understandings of stewardship take a much broader view, extending the context of

stewardship to an entire country's population, as in the biotechnology policy context, to anyone or anything facing the potential consequences of technological development, as in the ECL definition, or to the entire planet. Along with a shift in scope comes a broadening of the considerations required for effective stewardship. While a tech steward within a community of practice may focus solely on the needs and values of the community itself, a tech steward in the ECL sense is required to consider the possible effects of a new technology on a much larger and potentially more diverse group of constituents.

Conclusions and Next Steps

Our analysis identified distinctions and tensions that exist in meanings of stewardship across different contexts. Authors in these contexts position 'stewardship' variously as settler, paternalistic, hierarchical, anthropocentric, holistic, or ecocentric. A common theme across all contexts is the conceptualization of stewardship as ways of *caring* – however, the actors, motivations, and implications of that care vary greatly.

These tensions raise significant questions for engineers and engineering educators who engage with "tech stewardship" as a mindset, design philosophy, or pedagogical approach. First, are engineers to be stewards of technology in a managerial, hierarchical sense, with sole or primary responsibility for guiding technological development? Or is technological stewardship a distributed responsibility, in which engineers play a collaborative role? Second, to what extent should engineers consider stewardship to be a part of the technological design process? More specifically, can tech stewardship be assessed in terms of the outcomes and impacts of a specific technology, or should it be evaluated with respect to larger-scale cultural change, or 'protection' of societal values? Finally, to which constituencies are engineers-as-stewards responsible? Should they concern themselves with the needs of a particular community to which they belong, or for/with whom they are designing? Or does tech stewardship require engineers to consider the values and needs of a broader range of publics? Overall, to what extent is tech stewardship a realistic catalyst for cultural change within engineering? Engineers' and engineering educators' responses to these questions have the potential to reinforce a status quo of "design for technology" [40], to echo existing attempts to evolve the design process, such as responsible innovation [41], or present a radical reimagining of engineers' relationship with society, e.g. by inviting engineers to engage in collaborative stewardship processes that rejects hierarchical relationships between human society and the natural world.

Although these questions are not answered in this work, they serve as point of departure for those interested and engaged in work related to tech stewardship. In the next steps of our work, through interviews, focus groups, and document analysis, we will further explore these questions and the range of engineers' possible responses to them, and analyse the understanding of "stewardship" that the Tech Stewardship Practice Program enacts through its content.

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