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Metaphoring back in the climate crisis: Notes toward encouraging student engineer agency through metaphoring

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Abstract: In this work-in-progress, I consider the impacts of generative metaphor, metaphoring, and framing on student engineers' developing positioning relative to ecological issues in engineering. I consider how engineering, as a symbolic community, is impacted by metaphors and narratives that provide frameworks by which to understand engineering's relationship to the Earth and ecology. I consider the historical framing of engineering as a "socially captive" practice and consider challenges to that framing. Finally, I consider how knowledge and comprehension of metaphors and metaphoring can inform engineering education, and in particular students' ongoing interaction with ecologically-related metaphors that frame the agency they have access to in both their education and their future professional practice.

Keywords: engineering education; generative metaphor; metaphor comprehension; symbolic communities; ecolinguistics

1 Introduction: Engineering in a crisis world

It hardly seems necessary to argue for an increased focus on ecology in an essential, ecologically-impactful practice like engineering. So, I will state it briefly and move on: we are dangerously too late to any earnest attempt to meet the climate crisis. Given that we live in what Carl Mitcham (2014) calls "an engineered world" (Why Humanities, para. 8) it is easy to locate engineering practice in both the causes and potential solutions to the climate crisis. It is in this spirit that Mitcham calls engineers "the unacknowledged legislators of the world" (Introduction, para. 2), indicating—by borrowing Percy Shelly's claim about poets—that in many ways, engineering serves a kind of authorial function in our world. It follows, then, that engineering practice must be mindful of its ecological consequences—to both avoid and reverse negative consequences—if we, as a species, are to avoid the worst of those consequences.

That process of authoring-through-design-products depends on the metaphorical framings that underlay engineering practice. Those framings are deeply rooted in cultural, economic, and colonial history and are not easily rerouted. Historically, as discussed below, engineering in the West has been "socially captive" (Goldman, 1991; Johnston et al., 1996), meaning that it has worked at the behest of the power structures that hold decision-making abilities. That is, the social captivity theory argues that engineering has traditionally followed orders from governments,

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corporations, and institutions. This framing of engineering as a practice-that-follows-orders threatens to strip engineers, and student engineers, of agency and render them subjects of power who dutifully manifest the priorities of that power. The manifestation of those priorities, in turn, has played a major role in the ecological degradation and destruction that we, as a civilization and as a species, are still struggling to even acknowledge. Unless engineering can be reframed as an agentive, non-captive practice, it will remain at the dubious whims of the power that has historically directed it.

Reframing is possible, and in many ways underway, as evidenced by the theme the 2021 conference held by the Canadian Engineering Education Association: “Stimulating a Sustainability Mindset in Engineering Education” (2021). The project of reframing engineering for a crisis world, however, is far from done. The loci of power that have historically directed engineering practice are themselves undergoing major challenges and changes due to the climate crisis, and any resulting changes in direction will inevitably alter the directions of engineering. However, it is urgent that we consider not only the orders given to engineering, but also the role engineering itself plays in those decision-making processes.

In considering that role, and how it might change, we can start by examining how engineering is framed for students in their undergraduate education, and how social captivity is introduced and reinforced. To understand that educational impact, we have to first understand how metaphors and storytelling operate as framing devices for knowledge, and how they operate in engineering in particular. If we can achieve that, we might then consider how our students can turn their future work toward more beneficial ends.

2 Metaphors in and of engineering

Engineering and metaphors have a longstanding, complex relationship. Metaphors and symbolism guide engineering, but engineering artifacts also become metaphors for human ingenuity and humanity itself, given the incredible power they have to alter not just human life and society, but also the whole world. In his poem, “To Brooklyn Bridge,” Harte Crane (1933) contemplates that legendary piece of engineering design as a human achievement that has reached divine status. Addressing the bridge, Crane’s speaker implores it to “lend a myth to God.” This suggests a shift in perspective. If the bridge—an artifact of human endeavor—lends a myth to God, then humanity has grown godlike in its power to affect change in its environment. There is much more that could be said here (about God’s status change in particular), but even the suggestion of human engineering reaching divine status supports Mitcham’s (2014) view of engineering’s world-changing status. And it is important to note that, nearly a hundred years after the poem was written, engineering as a professional practice is still struggling to wear the kind of world-changing symbolism Crane suggests for it, and—more importantly—it is struggling to live up to the responsibility that that implies. It is in a strange place: world changing, but captive.

The implied shirking of responsibility here is one widely shared in our civilization, but engineering’s impact, and the particular history of how it frames itself in the world, makes it especially important to consider. Furthermore, engineering’s central place in the modern world makes it worthy of consideration both in its own right and as a vantage point from which to understand other aspects of our civilization as a whole. At the same time, engineering is a largely collaborative and highly multi-and-trans-disciplinary field, and engineering projects impact and are impacted by a wide range of stakeholders (both human and non-human), making it an ideal starting point for investigations into how our complex world currently operates and how it might be altered to serve our continuing survival. That is, engineering provides both the potential means, and a way (note: “a”, not “the”) to understand how we might mitigate humanity’s ongoing ecological destruction.

Thus, it behooves us to understand how engineering operates as what Kong (2014) calls a “symbolic community,” as that will provide insight into both engineering’s captivity and its potential for liberation. Like the rest of human endeavour, engineering is guided by principles, narratives, and frameworks that are captured in symbolism, metaphors, and conceptual frames. Kong (2014) describes a “community” as defined “by activities instead of language conventions” (p. 46) but “constructed through language and other symbolic means” (p. 49). So, while the activities of the engineering community define it, the identity built around those activities is linguistic and, I argue, largely metaphorical. Kong (2014) describes how activity is enabled by communicative mediation, but also how the mediational processes of framing determine the ultimate meaning of a community’s shared activity: “by engaging themselves in those activities, members rely on the use of meditational means including language, and through those means also develop some disposition and attitudes towards a group” (p. 47).

So, while it is easy to accept a simple framing of engineering as a problem-solving, pragmatic activity, we cannot ignore the way “mediational means” direct that activity toward specific (and impactful) ends, means, and goals. We must also note that the ends towards which engineering’s awesome power is directed are not predetermined, but subject to choice and decisions. How, and by whom, those decisions are made—and how that decision making impacts and filters through the practical activity of carrying them out—contributes greatly to the “disposition” of those in the engineering community. Understanding that disposition, and everything that feeds it, is urgent, because as Donald Schön’s (1979) theory of “generative metaphor” explains, that disposition helps determine how problems are identified, framed, and ultimately addressed. Metaphorical framing informs practice. In turn, practice—especially uncritical practice—impacts the kind of metaphorical framing utilized by, and accessible to, engineers. Framing becomes a choice for engineering: to uncritically accept captivity, or to push back, and in the process, generate a new metaphor.

Therefore, we must consider the metaphors that frame the disposition of the engineering community, and that thus impact the directions and goals of engineering activities. In many ways these dispositions are well known and well established, but in many ways, they are in flux. One convincing argument, as we have seen, goes that engineering in North America has historically been a “socially captive” practice. According to Goldman (1991), Johnston, et al. (1996), and Mitcham and Muñoz (2010), engineering is subject to the whims of powerful social forces—such as nationalism, extractive capitalism, and consumerism—that dictate the directions of its powerful potential impacts. The social captivity argument holds that such a framework allows engineering to position itself as a practice that simply carries out (with impressive rigour) the tasks assigned to it, for better or for worse. There is, of course, some limited agency afforded to engineering in this construct in that some specifics of how a goal is set may be left up to engineering designers themselves. Still, much depends on the goals that are set and the priorities of whoever it is that is making a specific project possible.

That is, of course, an oversimplification, and the actual history of engineering is far more complex—and, we should not forget, responsible for many of the feats, comforts, and tools without which the modern world would be impossible. Such positives, however, might only increase our desire for engineering agency, for if we are to survive the climate crisis intact (however that is measured), we will need engineering to be directed toward ensuring that survival, from both the loci of power and from within engineering itself. We need a beneficial engineering, and we need engineering itself to push for the beneficial and against the destructive.

3 Metaphoring out of captivity: Toward a framing of student engineer agency

The figure of the obedient engineer, it might be argued, is not necessarily a problem. After all, it is foolish to think, no matter who we are and what we do, that our agency can ever be unbounded, or that engineering in particular will ever be free of controlling power structures. It might also be argued that if the controlling power structures are just, wise, and pragmatic, then there is no problem with obedience. Indeed, a focus on engineering agency does not eliminate the need for reform of government or economic structures and it is certainly important that we all row in the same direction regarding the climate crisis. Even so, an agentive, critical, and self-reflective engineering culture would help push power in the right direction and serve as a check on power that is moving in destructive directions. Given that engineering is heavily reliant on institutions of higher learning for training, those institutions present the opportunity to address the need for what Mitcham (2014) calls, in his article of the same name, "The true grand challenge of engineering: Self-knowledge". In order to encourage such self-awareness at both the individual and community level, we can start by considering the role metaphors play in framing our students' understanding of engineering and its relationships to the wider world.

Luckily, the same metaphorical forces that frame engineering as captive can be used to move in the opposite direction. Schön (1979) and Mey (2017) suggest that framing and metaphor can be more than just an influence on knowledge and practice, but also a location for negotiating new perspectives. Shön introduced generative metaphor as a way to combat issues that arise in the problem-setting phase of social policy planning. By ignoring problem setting as a conscious activity, Shön argues, policy makers move directly to problem solving, without confronting the bias and limitations inherent to the approaches that are embedded in how they have framed, or set, the problem. The tacit and unacknowledged values embedded in problem framing are determining factors in the kind of solutions made available to the problem solver. For example, think of the framing of COVID-19 pandemic as a "war," and how that leads to solutions that are described in wartime terms, such as "mobilization". As with the COVID-19-as-war metaphor, the impacts of metaphor on problem setting and solving are often uncertain and highly debatable. A war and a pandemic are different in important ways, but there is *some* natural alignment between war and pandemic responses in terms of scale, resource distribution, and logistics, and so the expertise of war may lend some useful knowledge to fighting a pandemic. At the same time, the metaphor is obviously limited: a virus is very different than a wartime enemy. You cannot even attempt to win the "hearts and minds" of COVID-19, and a battlefield is very different than a hospital ward. The important point is that looking critically at such metaphorical framing reveals its often-otherwise-tacit meanings and allows for the metaphor and its framing power to be adjusted and redirected toward more beneficial ends. On the other hand, if the framing remains tacit and is not critically surfaced, it threatens to lead astray the activities it is meant to guide, due to misalignments between the knowledge domains that the metaphor is mapping between.

It is beyond a doubt that metaphorical framing impacts the problem-setting and problem-solving process, and so "frame awareness" should be a topic of focus for our students. Encouraging critical awareness of metaphorical framing and problem setting in students would give them a tool by which they can take agency over of the setting of the problems they take on in their design courses. Mey (2005) refers to such active framing activity as "metaphoring," and this transformation from noun to verb properly positions metaphor not as a static container of knowledge but as an active space where knowledge can be gained, and values and beliefs renegotiated. It is important to note, too, that metaphoring activity is dialogical in a Bakhtinian (1981) sense: there is activity in both the production of the metaphorical utterance and in its appropriation, and these activities themselves are part of a cyclical heteroglossia in which metaphorical framings are unified, challenged, changed, and (re)constructed on multiple strata: from the culture as whole on down to the individual conversation. To use Halliday's (2013) expression, these metaphorical framings are always "at risk" (p. 34) when they are instantiated within a language system, such as a course.

Important questions now emerge: are students aware of the fact that framing metaphors are alive and changeable? Do they feel empowered to challenge or otherwise actively appropriate those metaphors? Do they possess the cognitive tools (Arievitch, 2017) needed to effectively engage in metaphoring activity? However, before any of those questions can be addressed, we need to know how metaphors operate in our courses, as is.

4 Metaphors and pedagogy: Comprehension and the example of scope/scoping

Before we can discuss student use of generative metaphor, or metaphoring, we need to know which metaphors are important framing device within a course, and how students understand and make use of those metaphors. Beynen (2020) uses corpus analysis to capture some of the metaphors used in a course and analyzes metaphor comprehension in students, finding some preliminary evidence that metaphor comprehension ability is predictive of performance in the course. Though her study looks at additional language users explicitly, the specificity of engineering discourse—and the differences between it and high school-level academic and everyday English—suggests that fluent English users may also struggle to comprehend the metaphors used to teach key concepts in engineering courses. If it is true that metaphors are creating barriers to understanding core course concepts—as opposed to being vehicles for expansive knowledge—that is an issue that needs immediate attention. Beynen (2020) claims we need to know more about student comprehension of metaphor, but that in the meantime we should at the very least become aware of the metaphors we utilize and their potential impacts on understanding (p. 19). Beynen's findings also suggest that we should consider addressing metaphors and metaphor comprehension explicitly in our instruction.

Even without that understanding of student comprehension, it is beyond doubt that metaphors play a key role in reaching a shared understanding of core course concepts. Take the case of scope and scoping,[2] a core concept/activity across engineering design and in design thinking more broadly. Scope/scoping could provide a rich case study in the life of metaphor in a course. Based on my own teaching experience, and in my discussions with other teachers, scope/scoping is a difficult concept/activity for students to grasp. That is undoubtably because it is complex and highly context-specific. It is multidimensional, and the dimensions that matter most to it depend on a host of factors, including decisions that are unique to the decision maker. There is never a right or wrong scope, but only the one you have chosen, defined, and defended using engineering argument. Here is how the textbook my course uses defines scope:

> The definition of the *breadth and depth* of the problem to solve. Typically, the project requirements *define* the scope of the project, which in turn specifies what a design team will do for the client and what they will not do, i.e., *the boundaries* of the project. Defining

[2] Because scope is both a concept and an activity, I refer to it in the combined "scope/scoping" form.

> a design problem is sometimes called a *scoping activity*, and in some industries the project requirements document is called a scoping document (McCahan et al., 2015, p. 595).

The first sentence of this definition, alone, exposes the limitations of the generative metaphor of scope/scoping. An actual scope—of a camera, let us say—is two-dimensional. A camera's scope, through the decisions made by the photographer, determines, or frames, what is in and what is out of the photograph being taken. This is useful to us because scope/scoping in design thinking also involves making decisions about what is of concern in a given design project, and what is "out of the scope." However, as indicated by "depth and breadth," scope/scoping is actually more complex than the 2D visual metaphor suggests, as a camera's scope does not control for depth, but only focus and breadth.

When we consider the elements beyond physical "boundaries" that go into "defining a design problem," the scope/scoping metaphor becomes even more strained. Consider values: an ecologically-centred design philosophy would play an essential role in defining any design problem, and so it would absolutely be considered in any "scoping activity." Understanding how such values might impact problem-setting is going to require more than the "in or out" visual-based understanding generated by the scope/scoping metaphor. A value can define not just what is in or out of consideration, but also the quality and importance assigned to the human and environmental concerns at play in a design project. Scope/scoping, properly understood, is a complex concept/activity that moves well beyond the (still very important) practical considerations such as protecting against cost-overruns and the dangers of "scope creep," a term that defines a design project that has taken too much on and so cannot properly solve the problem posed. Scope/scoping must be understood as also potentially requiring (depending on the particulars of a given project) a deep understanding of the ethical, philosophical, psychological, sociological, and other forms of knowledge that might bear on a given project.

Thus, we have a 2D metaphor attempting to capture a concept containing multitudinous potentialities of meaning. But while the failure of the metaphor is assured, that does not necessarily mean we should jettison the scope/scoping framework. Metaphors are inherently imperfect, limited and slippery. They aid and contain knowledge, but they do so through what the poet Anne Carson (2000) refers to as "error" (p. 30) and "making mistakes/in order to engage/the fact of the matter" (p. 35). For instance, reading a difficult book is never actually a "slow slog," but the implied comparison to a difficult walking experience helps us understand what it is like to read something difficult. However, it will never completely describe the reading experience itself. We always have to eventually move beyond the framing metaphors to get beyond the initial understanding they make possible, so we can understand the thing itself, on it its own terms and in its own manifestation in the world. In the case of scope/scoping, it would be useful to know how instructors, experienced students and engineering professionals have moved beyond the 2D-limited framing of scope/scoping in order to construct a richer concept of the true nature of "scoping activity." That knowledge could provide insight into how we might guide students toward their own richer understandings. We should be mindful, however, that students have not yet developed that richer conceptual understanding, nor do they necessarily know how to (or even that they can) expand and personalize a metaphorical framework to better fit the concept and activity it is meant to express, and as they uniquely understand it.

As with so many other generative metaphors and conceptual frameworks, we need to know more about how students comprehend, appropriate, and use the scope/scoping metaphor. Understanding those factors could prove incredibly important in improving our instruction on this core concept. This highlighting of framing as an active, conscious, and controllable activity is transferrable to a number of other core concepts and activities as well, such as the metaphorically-rich use of the term “gap” to define design problems. And, of course, such an understanding of metaphoring will help students develop into professionals who are better equipped to work in a world where our generative metaphors are increasingly destabilized and found to direct engineering activity in destructive ways we can no longer afford to ignore. We could sum it up by borrowing and adapting a well-known cliché: teach a student a metaphor, and they may understand the intended associated concept. Teach a student how to metaphor, and they will be equipped to unpack, understand, and use metaphors—and to push back against them.

5 Future directions: Building a base for life-long metaphoring practice

This paper has proposed that generative metaphor awareness, frame (re)structuring, and metaphoring activity should be a subject of critical reflection for instructors and that we should consider making metaphoring an explicit focus of our instruction. This approach would allow us to know how metaphors operate in our courses, but also how metaphors live beyond our instruction. Leontiev (1978) describes how “meanings lead a double life,” operating in the realms of social meaning as well as in “personal sense” (p. 89-90). Likewise, Halliday and Matthiessen (2013) describe how texts are both based on contextual circumstances and constitutive of those contexts, meaning that every time a student uses a metaphor in a course, or beyond, that utterance feeds back into the ongoing construction of the relevant contexts, potentially reaffirming or altering (however slightly) those contexts and the language systems in which they are embedded. I call this student-metaphoring activity “metaphoring back” to highlight the agentive potential of students’ metaphorical activity, in both appropriation and utterance.

To return to the initial motivation behind this paper, I predict that student agency in metaphoring activity can be found to have lasting impacts on the decisions students make when they eventually find themselves in positions of authority and responsibility. If true, this would support an argument that metaphoring should be considered a lifelong learning skill. Especially in a world marked by rapid changes, immediate challenges, and ever-looming climate disaster, the ability of engineers to critically examine the metaphors embedded in their design activities and directives will only grow more urgently needed.

6 Metaphoring for survival: Ecolinguistics

Aaron Stibbe (2015) presents Ecolinguistics as a theory by which to gauge the ecological benefits and destructiveness of the “stories-we-live-by” as well as the metaphors involved in those stories. Like Schön (1993), Stibbe views these narrative-and-metaphor-driven framing practices as essential to guiding us toward different, more sustainable futures, measuring the value of framing by assessing the beneficial or destructive outcomes they produce. Nowhere is it more important to consider this than in engineering, where the decisions made have such profound impacts. The impacts, surely, will remain. The question is: will they be beneficial or destructive? If students are better equipped to critically engage with the metaphors they are presented with, and if they are able to metaphor back, it will become possible for them to develop into professional engineers who do not cow to power, but who understand how metaphoring works at every level of the decision-making processes that lead to engineering projects being implemented. Instead of engineers as obedient followers, we would have critical practitioners who would provide a check against the further avoidable (and wilful) destruction of the Earth. This would not be the answer to the problems we face, but it would certainly play a part in any mitigation strategies we employ.

As I write this, we in Canada are learning a new term, "heat dome," as the western provinces swelter in life-threatening heat made worse by climate change (Gallardo, 2021). Engineering, in large part, made this condition possible through its essential part in the modern industrial world, its techniques of resource extraction, and a host of other climate-changing discoveries and activities. It has also made carbon capture and solar energy possible. While the climate's future is daunting, it is important to remember that the future is unfixed. Allow me to show awareness of my metaphor: the future is unfixed in that what is broken is not yet repaired, but also that our future course is not yet set. One of our goals as engineering educators, then, should be to show students how metaphoring can be a practice in which their agency might express itself, for it is they who will be doing so much of the fixing we will need.

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