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Managing Polarities: Perception of Value, Designer Roles, and Organizational Conditions that Influence Design Outcomes in Mechanical Engineering

Ms. Minha R. Ha, York University

Minha is a PhD Candidate in Mechanical Engineering, whose qualitative research focuses on the socio-technical knowledge integration in engineering design practice. As an interdisciplinary researcher with formal training in Molecular Biology and Education Research, she integrates grounded theory and Critical Discourse Analysis methods in order to study the transdisciplinary aspects of responsible design. Inquiry learning and knowledge co-creation are at the heart of her teaching approaches, whether in lecture, workshop, and laboratory settings. She has been actively involved in ethics, equity and leadership education in engineering since 2011.

Dr. Aleksander Czekanski , CEEA-ACEG

Dr. Aleksander Czekanski is an Associate Professor and NSERC Chair in Design Engineering in Lassonde School of Engineering at York University, Toronto. Before beginning his academic career in 2014, Dr. Czekanski worked for over 10 years in the automotive sector. Dr. Czekanski attention is dedicated to newly established Lassonde School of Engineering (York). He devotes his efforts towards the enrichment of Renaissance Engineering program by including interdisciplinary learning, industry collaboration and designing for positive social impact which contributes to the uniqueness of York's engineering program. As an active participant in the establishment of the undergraduate and graduate Mechanical Engineering programs, his attention is devoted to providing students with both experiential learning and soft skills.

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Abstract

Design engineers can greatly contribute to the growth of a business organization by not only creating relevant, contextually fit solutions for clients, but also by providing resilient responses to the changing constraints and opportunities external and internal to the organization. Unfortunately, the value-adding role of designers and indeed design project successes can be hindered by inadequate management of organizational tensions that persist over time and are widely experienced as paradoxical. Adopting the concept of 'polarity management' by Barry Johnson, this paper aims to unpack the nuances of two particular polarities: (1) Design Rigour vs. Cost Effectiveness, and (2) Collaboration vs. Efficiency.

The data are drawn from a larger grounded theory study on sociotechnical knowledge integration in engineering design. Semi-structured in-depth interview data were examined to identify the institutional and discursive barriers to designers' effective value-creating roles, and compare effective/ineffective management practices that address the two selected polarities.
Unresolved polarities contributed to the problems of disconnect and misalignment that impeded effective design and/or caused loss of value in the project lifecycle. Comparative examples helped identify possible organizational strategies to enhance holistic design, responsible collaboration, and effective input among actors. Three sets of learning objectives are also proposed for engineering management or design curricula.
The analysis also identified important discourses and perspective changes needed in order to support effective polarity management. The findings provide a useful example of discursive mediation between organizational culture and organizational practices.

Introduction

"Organizations and nations are born into [interdependent pairs of polarities] from their first day of existence – How do we Centralize to coordinate our Parts into an integrated Whole AND Decentralize to allow our parts the freedom to be responsive and take initiative?" (Barry Johnson, 2014)

Polarity Management. There are organizational aspects or expressions that are essential for the organization's success, such as collaboration, efficiency, service quality, flexibility, and innovation. These organizational aspects are expressed in various structures, processes, discourses, and decision priorities of the organization.

Some of these organizational aspects (desired or required approaches of organizational practice) appear to be polar opposites of each other (e.g. cost effectiveness and service quality; individualism and collectivism). Such polar opposites ('polarity pairs') are paradoxical because they are inter-related and *interdependent* despite the seeming contradiction [1]. Undermining one polar end directly undermines the other. In this way, they are not merely two competing choices ('dilemma') [2]. Without a conceptual understanding that integrates the polar 'opposite,' and even different types of polarity pairs, into a unified whole, it may be difficult to assess the value lost from undermining the synergies or alignment between different organizational aspects.

The term ‘polarity’ reflects the way certain organizational aspects are commonly perceived as irreconcilable as co-existent. When the resources required to conduct various organizational functions are finite, one can imagine how difficult it would be to negotiate priorities when organizational actors or units have a hard time seeing the value of organizational aspects other than the ones they are advocating for. The tendency to reduce the complexity of organizational life into what is explained only by one or few of the organizational aspects, cannot but result in a ‘paradox’ - the organizational elements are logical when considered independently, but seem contradictory when juxtaposed [2]. In other words, without understanding their interdependent relationship, various organizational aspects are conceptualized as mutually exclusive.

A coherent framework is needed, one that explains the interdependence between, the simultaneous co-existence of, and the necessary synergy of various organizational aspects. Since the dissected, narrowly defined organizational success (e.g. “it’s all about task efficiency”) fails to explain the lived experiences of the ‘life’ or the success of an organization, the empirical data must help improve the theoretical framework by which the organization can be understood and studied (see [3] for the explanation of the bilateral relationship between theory and the empirical world).

The world of engineering design practice presents an interesting challenge to an oversimplified economic analysis of the business organization. Design has an inherently emergent inquiry orientation, where contextualization (learning from, interacting with, and responding to the inputs of stakeholders in specific time, geographical, social contexts) becomes an extremely important factor of project success [4]. The design output must meet a real need in ways that reduce barriers to adoption and create tangible value for customers. While companies such as IBM explicitly promote and teach design thinking as a core skillset, many existing management approaches and organizational models do not necessarily share the same expectations or assumptions in terms of the processes, interactions, and relationships by which a successful business is created.

This paper explores the tensions or organizational polarities that are experienced by design engineers (hereby designers) in industries where mechanical engineering has a significant presence in the product development. By examining how the designers uniquely experience and address polarities that affect their design work, this paper presents potential conceptual frameworks that highlight and integrate some of the pertinent, interdependent organizational aspects. The ways in which organizational polarities affect and are addressed by the designers, also provide insights into the nature of a designer’s work that may not be captured in formal knowledge. Thus, new learning objectives are proposed to enhance both the design and management education of engineering students.

Methodology

This paper draws from a larger study on the sociotechnical knowledge integration in engineering design, involving engineers in informational interviews (5 male: 2 female), online surveys (7 male: 5 female), recorded in-depth interviews (10 male), and feedback sessions (6 male: 4 female) on the grounded theory findings. The resulting grounded theory analyses were presented to male and female engineers in diverse fields of engineering. Their inputs have elaborated and sharpened the understanding of the conceptual relationships and their represented realities in the engineering workplaces. Based on the emergent findings in a larger grounded theory study of designers who identified challenges and barriers to value maximization of their design work, this paper examines two interdependent polarity pairs (hereby polarities): (1) Design Rigour and Cost Effectiveness; and (2) Collaboration and Efficiency.

Grounded theory methodology [5] is well-suited to generating or advancing theory based on empirical data, instead of being limited to imposing an existing theory onto the data. Rigorous coding procedures are applied to the qualitative data, to develop categories, identify causal relations, and find counter-evidences. The emerging theory keeps at its centre the designers' **actions and interactions** that respond to a particular phenomenon (e.g. sociotechnical complexity of the design problem), and allows for variations in the data by explaining the relationship between mediating factors and outcomes of such action/interaction strategies. Because the norms surrounding the organizational polarities involve perception, analytic methods drawn from Critical Discourse Analysis [6] are also applied to the qualitative, in-depth interview data. In particular, the analysis aims to reveal how discourse is used to make certain realities **visible or invisible**, to assert certain assumptions and priorities, and to construct the **roles** of actors involved in the design project. This type of rhetorical analysis [7] questions the logic given to justify particular views and actions, and identifies discursive barriers to reconciling the organizational polarities. Combined, the grounded theory analysis reveals the value-adding strategies of designers that can go unrecognized, while the rhetorical analysis reveals the ways in which discourses must change in order to support or enhance the polarity management strategies.

The in-depth interview participants included in this paper were involved in design projects in which mechanical engineering has a significant presence. Their organizations' core businesses provided design solutions to educational and consumer space clients, with relatively low regulatory intensity compared to some of the participants' former experiences in the military, aerospace, medical, or nuclear energy sectors. Interview quotes are provided by participant pseudonyms.

Table 1. Interview Participants

Participant Pseudonym	Demographic Information	Design Experience in Industry
Cam (Participant 4)	Male, 35-44 years of age	15 years
Bee (Participant 5)	Male, 35-44 years of age	15 years
Cosmic (Participant 6)	Male, 45-54 years of age	30 years
Radiant (Participant 7)	Male, 35-44 years of age	20 years
Cube (Participant 8)	Male, 35-44 years of age	20 years
Yellow (Participant 9)	Male, 35-44 years of age	17 years
Tech Rep (Participant 10)	Male, 25-34 years of age	5.5 years

Findings and Discussion

Three examples of organizational polarities are discussed (Table 2): Design vs. Cost, Collaboration vs. Efficiency, and Cost vs. Accountability. Each example is described below.

Design Rationale vs. Cost Effectiveness. Rather than the commonly known 'quality vs. cost' polarity, this study found that the key tension regarding 'cost' was in how 'design' was viewed, treated, supported, and managed. As will be discussed further below, 'design rationale' centralizes the goal of value creation and value maximization, which includes quality but much more (i.e. contextual fit, whole system alternatives). The dominance of 'cost' logic often focuses on the single transactions (i.e. purchasing of specific parts), that does not take into account the systemic effect of the part change, nor makes room for alternative systems-level arrangements (i.e. differently arranged interdependencies).

> *… some companies where internally it's mandated to have a cost reduction of x percent every year. So often engineering and purchasing will come together and purchasing says, Okay, you need to reduce your cost of this product by x amount this year. And then it keeps moving. (Interviewer: A commitment to a continuous improvement?) I don't know if continuous improvement is the right terminology. Continuous improvement implies… the goal is to improve the design to achieve greater benefit. [But] here it's all about cost reduction. So it's about maintaining or being able to execute the same level of benefit that the product provides, but at a lower cost… I think one of the shortcomings might be engineers tend to then, I don't know if 'forsake' is the right word, but 'accept' lower quality in certain areas. Accept, make sacrifices to achieve [cost reduction].* (Tech Rep)

It is important to note that the designer interprets the cost reduction mandate with 'retained value of design.' Not compromising the value of design ('same level of benefit') is what justifies the cost reduction strategy, but in reality, compromise in quality is treated as the norm. Decreasing the value of design work inherently contradicts design thinking, and yet the imposition of a fixed cost reduction target pressured the designers to undermine the quality metric.

Simultaneously, simply removing the cost constraint is not what ensures maximum value of design. Rather, many examples showed that the designers expect to manage multiple constraints simultaneously, and requires a degree of autonomy and negotiation in order to do so.

> *I think it's establishing the budget right off the bat with engineers. So having the **transparency**. There's, for example, one, um, this one customer, they [show an opposite example of having no cost target]. So engineering kept over-engineering… then Purchasing would always come back and say, 'No, **you need to make it cheaper.' But they wouldn't necessarily provide a target** … So there's some **vagueness**. And so part of that I found is part of **company culture**. And so that company was a startup and I think that culture and lack of experience had a **big impact on how the design is made**. But as they grew bigger and more corporate mentality was established, more **established processes**… [to] establish better budgets.* (Tech Rep)

Responsible Collaboration vs. Compartmentalized Efficiency. Organizations can create silos based on the assumption that separation by function increases focus and efficiency of individual business activities. However, multiple examples are provided that highlight why silos jeopardize

collective efficiency, as well as productivity of individual units. Yellow recounts the experience of his organization undergoing changes between both silos and open/collaborative models:

> *So we try not to have silos … The company started like that. Organically, very flat and open and … have us [the engineers], and have different contributions in different sort of roles [including] marketing, sales. And then we went into more like a Silo Organization for efficiency's sake. We did for a few years. I always found it, well, we reverted [back]. We changed our mind like other companies do, I hear. So what didn't work was the lack of communication between departments. So we could have some efficiencies within departments, by really focusing on some technical details, but we were losing too much by doing that in terms of interaction with the other sides of the company… So the big picture was getting lost … Most people were less and less aware of what was happening outside of the sort of area of their expertise … It also affects the quality of what you produce ultimately because people placed in [one unit] need to be aware of, I mean, ultimately it all comes back to the user experience … we need actually the feedback loop basically from sales who talk to customers and our users most of the time. … what are the people's needs, [in relation to] what we're putting out there.* (Yellow)

Compartmentalization (reducing dialogue and shared problem solving between departments) coupled with physical separation led to a disconnect between teams, which led to a loss of context. The context, or 'big picture,' of the user needs is a source of crucial information that makes the technological solution design work relevant and fit in a timely and locally specific manner [4]. It can also be argued that there is a second type of context that is relevant, namely the context of the workplace processes. Seeing how different units contribute to the shared goal and collective success, allows individuals and units to be creative and responsive in making distinct contributions to the whole. Losing sight of context also means that one loses sight of the work's impact – which has a direct consequence on the designer's morale.

Cost vs. Accountability. Tech Rep (TR) provides a telling example of the interplay between both the design-cost and collaboration-efficiency polarities. It reveals how perception of value-add or value-loss leads to business arrangements that either rewards responsible collaboration, or self-interest of external entities. Here, TR describes a particular design business (Original Equipment Manufacturer, OEM) experienced challenges working with an overseas Contract Manufacturer (CM):

> *… when looking for replacements [in redesign], sometimes it's no longer even driven by what we call the OEM … They don't drive those changes anymore. Now it's whoever they contracted the manufacturing to. And so this is a third party then, [who] comes back to them and says, okay, we're going to make these changes. We're going to decide who we're going to source from. We just need to qualify them and say, yeah, it's okay to go with these guys. But we decide ultimately, yeah. So [the OEM engineers] lose that design power.*
>
> *… another [OEM], they have a big Chinese or Taiwanese based on contract manufacturer … [the CM has] so much power, that sometimes they'll switch out components without informing [the designers of their client company] or they'll create*

significant barriers for [other] vendors that the design team approved of. But in that space they're motivated and incentivized by their local manufacturers. And so they create additional barriers for other people, [in order] to ***incentivize their own supply chain****. (Interviewer: So there's conflict of interest) There's a lot of [it], especially in the consumer space … because the product design is* ***segmented*** *across different industries…* (Tech Rep)

Tech Rep brings attention to the inherent value built in a local industrial ecosystem. The importance of sustained business relationships motivate and reward mutual accountability and trust. When the initial purchasing cost does not take into account the cost of losing a relationship that values accountability and collaboration, the problems of distance (i.e. difficulty in oversight and communication, reducing reciprocal influence) and misalignment (i.e. disproportionate decision authority distribution, and competing interests) can be introduced to create unanticipated challenges (which result in additional cost to address, including hiring third parties to facilitate oversight). The reward structure and business arrangements create different levels of freedom (i.e. in this example, more to the CM than the OEM designers), further exacerbating the limited influence the designers had in evaluating the potential CMs. Business arrangements (based on trust) and reward structures reflect how (and whether) the organization sees where value is added and lost, regardless of its accuracy against the entire project outcomes. The failed expectations in quality or contractor behaviour are a reflection of faulty assumptions.

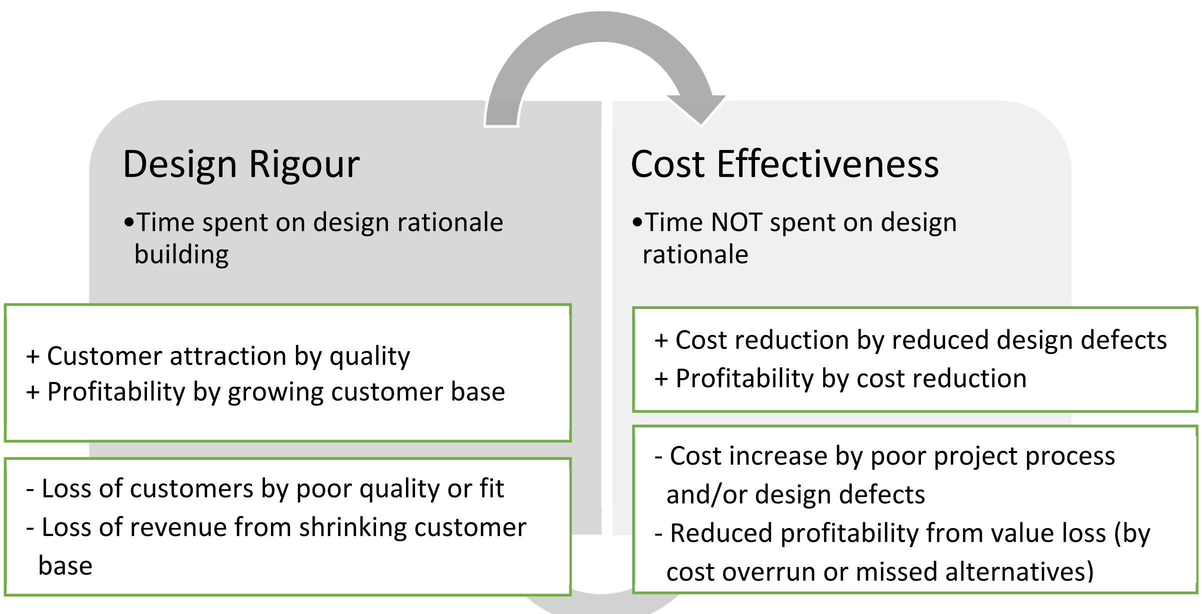

Figure 1. Interdependence Between Design Rigour and Cost Effectiveness

Figures 1 and 2 capture the interdependent relationships between the organizational aspects that constitute the two main polarities. Table 2, on the other hand, compares the role of perception and discourse in managing the polarities, including the designers' approaches to resolving the polarities.

Table 2. Comparative Examples of Organizational Polarities

	Quality Design – Cost	Collaboration – Efficiency	Cost – Accountability
Signs of Unresolved Polarity	• Pressure to save the costs upfront in the project, but quality is undermined • More time spent to fix problems rather than do proper design work first • Poor negotiation of multiple constraints, working with limiting partial information	• Delays and redundancy in obtaining the right information for successful design • Departments unwilling to help one another	• Business actors pursuing profit interests that do not promote a win-win • Poor accountability, lack of oversight to ensure quality delivery
Discursive Challenges	• “Don’t change it if it isn’t broken” • “Cost is king”	• ‘Interaction time is wasted time away from productivity’ • ‘We do not have the resources to bring different departments to work together, but we can afford to have an entire department repeat tasks or have two departments doing the same thing’	• “Cost is king” • ‘All suppliers are the same, they only compete on the price’
Effects of the Discourse	• View quality as an independent constant • Value losses due to improper design are not accounted for process improvement (failing to reflect on past redundancies and defects) • Control approach rather than co-creator approach, leaving designers with only partial information and no room to make input to decisions	• Individual unit performance kept separate from collective success of the business organization • View performance as a constant output, without regard for the quality input/learning required for quality output • Unfitting decision authority over design projects, that impedes design work • Penalizing behaviours that help one another	• Single transaction arrangements seen as the guarantee of successful business collaboration • Downplays the value of the mutually supporting effect of local industry ecosystem, which is based on trust relations that require long-term view • Unfitting decision authority over design projects, that impedes design work
Main Challenge	• Multiple constraints must be considered and defined together, not in isolated segments. Right input required, then designer must work out the balancing thresholds.	• Gaps in expertise • Missing knowledge of the in-use contexts or the client’s needs/objectives	• Limited information and overwhelming number of vendors to choose from
Designers’ Action-Interaction Strategies	• Integrate right input • Balance trade-offs • Create new options for whole design value • “You get what you paid for” – Maximize value (cost effectiveness) and minimize downstream trouble shooting, waste or loss	• Active inquiry: information collection, joint problem solving, shared idea generation	• Testing and evaluating the quality, value and trustworthiness of potential suppliers, vendors, contractors • Communication and expectation management, oversight • Joint problem solving

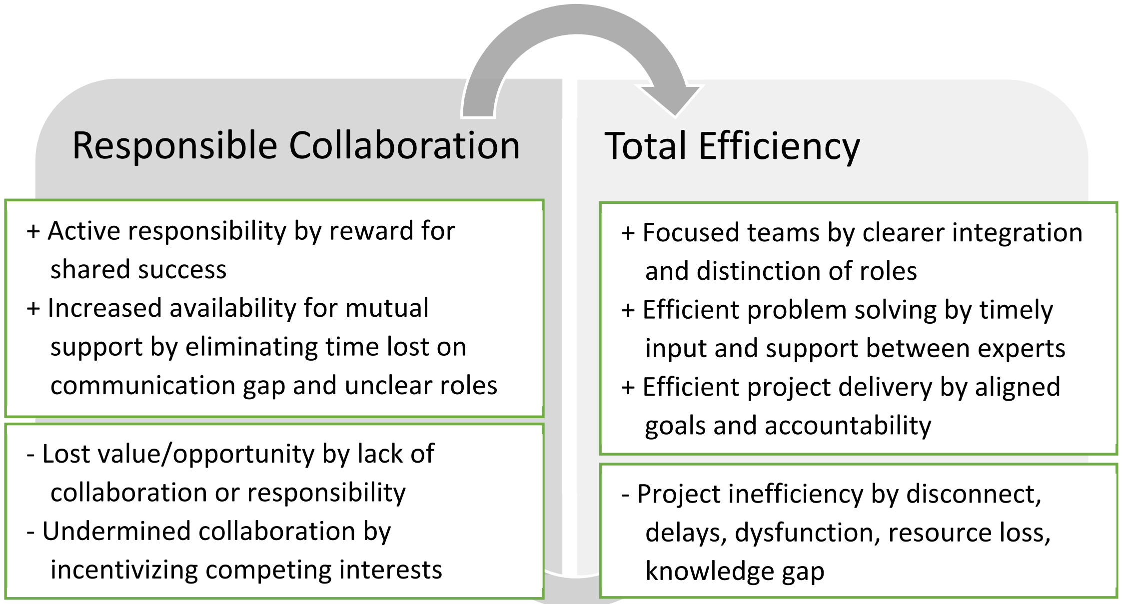

Figure 2. Interdependence between Responsible Collaboration and Efficiency

The goal of polarity management is to maximize the positive aspects of both polar opposites, and minimize the downsides of both [1]. However, lack of concept clarity or missing mediators can make it difficult to identify the conditions that enable maximum upsides for both elements in tension. A rhetorical analysis helps articulate the assumptions that create the tension (Table 3).

There are several common themes across the selected polarity examples. First, there is a tight relationship between perception (i.e. recognized value-add or value-loss) and business decisions. When quality is assumed to be independent from cost (i.e. time on design, price on material or parts), then the quality considerations do not become constraints in the cost targets (rather, it is erroneously assumed as a constant). The hypervisibility of partial costs (e.g. time on design, immediate purchasing price of supplies) masks the costly losses in project life cycle (e.g. time on fixing design defects, under-delivery by contractors, opportunity cost from missing critical intelligence) and thus limit process improvement.

When the actual cost of losing quality enters the decision consideration, however, it quickly becomes obvious that saving some of the initial purchasing cost is not worth losing customers due to overall product failure or poor performance. In other words, quality becomes part of the business imperative and competitiveness equation in complex technological solutions:

> *… one supplier had a long standing customer that they've been with for many years. Suddenly that customer cut off and said, okay, we're not buying from you anymore. We're going with these guys because they're cheaper. And then a few months later they came back running and say, Oh, no, we messed up. You know, the material quality isn't as good as they promised it would be. It wasn't as good as all this.* (Tech Rep)

Table 3. Competing Views on Design and Collaboration

	Root Causes
Why design investigation or autonomy are discouraged:	• View of time as cost: only initial time is visible • 'We do not have the resources to bring different departments together in the beginning, but we can afford to have an entire department repeat tasks and have two departments doing the same thing.'
Why design investigation and interaction are encouraged:	• View of time as cost: recognizes entire project life cycle and repercussions of design defects • Reducing loss by thorough design in early stages, requiring less time to correct design defects or errors or dealing with quality issues from external contributions
Why collaboration is discouraged:	• Views time-on-task as the only measure of productivity • Productivity viewed as constant and drawn from a void • Fear of losing focus or distraction from worker productivity • Belief that views that the company does not have the resources to bring different departments together in the beginning, but greater acceptability of affording to have an entire department repeat tasks and have two departments doing the same thing.
Why collaboration is encouraged:	• Views output over project life cycle as measure of productivity • Recognizes the need to learn, obtain feedback, and collaboratively generate insight in order to have maximum output • Undocumented loss of productivity by gaps in information, disconnect from advances in research/industry/market, no single unit has all the expertise or resources to deliver a complex engineering project

Second, the perception of value creates reward structures that motivate actors in ways that either undermine or enhance the overall value (including cost effectiveness, efficiency, quality) of the project. What is made visible, or recognized as valuable, gets rewarded. The alignment of reward with shared success is key. In addition to the example above that demonstrates misalignment (OEM and overseas CM), Tech Rep explains the power of design thinking as well as having 'value creation' as the core motive of business, being rewarded by new or repeat customers:

> *this one customer engineer had us come in [to help] for a shortage of materials from another vendor. We came in, we looked at the product and said, 'Okay, we can supply the same material, but we can actually also offer a design change.' And so we provided a design change with the similar material and* ***we saved them 40% of what they were paying previously on that material*** *… For me, we're* ***focused on creating value*** *for our customers. I think it we're driven to do that because of the competitive landscape […] 'Cause for us to be* ***successful****, we need to be creative in that way to provide, to offer creative solutions similar to what consultants do or they need to start thinking outside of the box to win more business, more clients. So we take a similar approach where we have to also bring a unique proposition. Otherwise, there's no* ***value*** *that we can bring to the design engineer.* (Tech Rep)

Of particular importance is the disregard paid to the role and nature of 'design' work that creates business success. (Appendices I and II present a very few examples of what the designers do to establish the design rationale.) Here again the perceived nature and work of technology design plays an important role. For example, when specification sheets become the only thing that an organization recognizes as the indicators of quality, we observe that non-experts are making design choice decisions that override the designers' work (thus costing valuable time resource), and that designers are not welcomed to share authority and influence in key decisions (thus missing critical input):

> *… when the purchasers or buyers get it, they just see numbers or what we call a spec sheet… And if they're able to match that with an alternative vendor that's cheaper, but then the engineer hasn't had the chance to do testing on it … they may place significant pressure to that engineer… "Hey, you need to look at this guy instead. I need you to do this, the same test, but I need you to shift your focus here" … even though the engineer's already completed testing and has already qualified and approved the particular component for his design, he then has to do the same thing, the same tests, and kind of go back into a circle with that new vendor because Purchasing mandated it … An engineer typically does not decide on a particular component unless they have done a prototype test to it.* (Tech Rep)

Part of the contextualization work [4] that the designers conduct also includes the broader market trends, and long-term strategies for business growth.

> *Yeah, so okay. If you look at the history of this company, um, the origins were in a relatively narrow but important field within mechanical and electrical engineering. It's called control systems. Control systems in an academic sense has a very narrowly defined, uh, context and it's defined by mathematics somewhat by computing and some experimentation and so on and so forth. What this company was strong at, and it in fact dominated the field from a practical lab equipment point of view. If somebody did not want to go through the trouble of designing their own equipment [in a particular sector], there was only one option: us. These guys just nailed that market. looking forward, though, for us to grow as a company and to go into new fields or adapt to some of the changing views on control systems in the modern world, you know, we had to, as a, as a company grow beyond that original narrow definition that we were so comfortable in. And that that connected to almost everything that we did, connected to the products we design, how we support it. we create a course material, What does that look like? And, and so rethinking how that, that strong initial start, our original narrow specialization, rethinking it in a way that it can efficiently get us to new fields like robotics and IoT and AI and that kind of thing. Um, that was for me one of the most exciting challenges in overcoming that inertia.* (Cosmic)

In the context of rapid changes in technological and social change, it is expected that an organization's effectiveness and resilient adaptability will benefit from supporting designers (or engineers who practice holistic, designerly systems thinking) to engage in value-creating actions and interactions. The disregard for the rationale-building, inquiry and knowledge co-creation work of designers, by imposing a narrow metric of success such as 'cost' (in its fragmented, immediate transaction sense), may undermine the full potential of what the designers bring to the table, including opportunity costs.

In contrast, a comprehensive view of design, and the designer's work, offers a promising framework that resolves the polarities and integrates the distinct and interdependent aspects of business success into an organized design project process. Mainly, the key action/interaction strategies include:

1. Ensuring the right input towards defining the needs, constraints, available options, barriers to success
2. Building collaborative relationships through joint problem solving with internal and external actors, including clients, for shared success, responsibility, rewarding trust
3. Creating whole solution approaches to balancing the trade-offs, meeting constraints, and maximizing the value of design output for customers and the business organization

Recognition of these value-creating actions and interactions by designers leads to the following recommendations for business organizations and engineering educators:

1. Develop skills and improve strategies for whole design, with creativity, resourcefulness, and sound rationale
2. Clarify roles and the timing of the actor interactions that need to occur during the life of a design project
3. Reward the behaviours that foster responsible collaboration among various actor relationships

Educational Implications. Two key approaches were identified to resolve the above-mentioned polarities and enhanced design project success: (1) holistic thinking for value-adding design; and (2) responsible collaboration. In addition, designers added critical value to the business organization and their clients by performing (3) bridging roles, that facilitated collective learning, new systems knowledge creation and translation, responsible collaboration and value creation for multiple stakeholders. Accordingly, proposed learning objectives are organized in Table 4.

Engineering design projects are complex endeavours that require multiple disciplinary expertise to be integrated throughout the project, and no single unit has all the information needed. Coordination around the right inputs, that support effort design rationale building, would prevent design defects, redundancies, and lost work due to overridden decisions. A reward structure should be thoughtfully planned, to encourage effective contribution to the design work, and align actor interests such that a shared success would be rewarded.

Each set of learning objectives may be further studied in the framework of threshold concepts [8], [9]: Which learning objects are difficult to achieve, yet critical for holistic thinking, interaction roles, and interest alignment? In what sequence should they be learned, and how can such skills be recognized and rewarded in the formal curriculum?

Table 4. Proposed Learning Objectives for Engineering Management and Design Education

Value-Creation Strategies	Knowledge: Multiple Systems View	Skills: Aligning Actions, Demonstrating Value, Building Learning Relationships
Holistic Thinking for **Value-Adding** Design	• Industry ecosystem • Sociotechnical systems	• Create alternative combinations of design project options • Resourcefulness • Identify what adds value to different stakeholder needs in unique contexts
Bridging Roles (of individuals) for Knowledge Work	• Network view of actors • Multiple business perspectives, including marketing, finance	• Interactional learning • Construct an integrated knowledge of stakeholders' local contexts • Build mutual trust and partnership through facilitated co-creation • Emotional intelligence for dialogue • Knowledge representation and negotiation
Responsible Collaboration (between units or organizational entities)	• Network view of actors • Actual costs and value-adds associated with assumptions • Types of interactions with appropriate input timing	• Align authority distribution, reward metrics and interaction environment/processes with the desired behaviour • Evaluate trustworthiness based on track record of performance

Conclusions

Designers add tremendous value to their organizations when they are able to exercise their responsible creativity. They create value for customers with timely relevance, by knowledge inquiry into the user contexts; they identify holistic value-adding alternatives by staying knowledgeable in the industry ecology and trends; they develop new and prolonged engagement with customers by inviting them into collaborative problem solving, thereby building trust and effective problem definition early in the project.

Designers faced challenges for their work when other actors were not contributing the right input at the right time. In some cases it was the absence of input (lack of collaboration or disconnect), in others it was input that made designers' work ineffectual by decision or process override (ad hoc process or disproportionate control). The analysis identified two major sources of such *disconnect* and *misalignment*: (1) The organization's **reward structure** for both internal and external actors; and (2) The organization's **normative perception** of priorities, roles, processes relating to engineering design. The reward structure has a direct impact on actor behaviours. The perceptive norms can be exhibited more subtly in the actions and discourses that justify the existing patterns.

The common root cause of organizational barriers to design and designers' maximum effectiveness was identified to be **a skewed visibility** of value-add and value-loss associated with the actor behaviours that ultimately affect the business outcomes of the organization. Redefining the polarities is part of designers' efforts to resolve the tension, and also calls for effort to… useful in making such value-add or value-loss outcomes more visible, in order to present alternative strategies in engineering management.

Relationship between design and management call for a more comprehensive model of design practice that places design thinking at the heart of the organizational culture, one that challenges reductionism and isolation from important contexts (e.g. changes, nuances, knowledge that is gained only through relational learning, meanings and values). It emphasizes value creation for multiple key stakeholders, without which project success cannot be assumed. It also demands an explicitly monitored life cycle view of true project costs and profitability estimates, looking beyond previous design arrangements to identify newer mix of alternatives, and looking at what is motivating value-adding or value-decreasing behaviours of actors.

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Appendix I. Designers Balance Competing Constraints and Trade-Offs

Design thinking inherently involves constructing a detailed rationale that answers questions about the purpose, objectives, and the best method to create value. Designers assess many types of decisions that affect the project and the business bottom line. Assessing constraints, the designer also explores new options that create overall project value.

> *… I recently had my yearly review. One of the things the praises [given to me was] 'You understand exactly our business model. You understand exactly where the money should be invested.' Whenever I get out a request for an improvement or for a job, the first things I do, I just compare that to our business model … 'We'll have to throw a lot of money on it, but do we have the money?' Then you start thinking of [options], 'You can get somebody else to solve for it. [It makes sense to] pay for that [instead of doing it in-house].' Engineers tend to want to solve everything by themselves, even if it's out of their field. A lot of mechanical and electronics engineers… they just want to write a code for it and kick it up in the market. But there's just a lot more involved than just writing code.* (Radiant)

> *What is it addressing? What needs, if there's a need for the company… the* ***balance*** *with cost. and the alternatives. So, so part of the use cases is like, you know, you've, you defined, The good thing with a use case, you've defined a use case, Okay. So you say this product would address that use case, right. Is* ***there any other alternatives*** *to address the same use case? From our product line, from maybe modifications, alternatives to, it's like basically the, the hope and the idea for the project proposals you get, you* ***build*** *a case,* ***propose to a point where the final conclusion from the stakeholder is that, yes we will build this product to do this, because of all the reasons****.* (Bee)

When business success is aligned with value maximization of the design work, it is simply unreasonable to assume resource effectiveness and efficiency by compartmentalization or isolation of designers from information about the contexts, as well as the freedom to explore and assess alternative whole solutions. Designers, in their holistic design work, add tremendous value to both the business organization and their clients.

Appendix II. The Investigative Nature of Building Rationale for Engineering Design

Here, Bee is not referring to the generalized, abstracted model of a design stages often referring only to the information object deliverables (e.g. concept design, design criteria). Rather, Bee brings attention to the **rigorous investigations and evidence-based self-critique** that are essential to justifying 'why' particular choices, requirements, decisions are made. Engineers handle large volumes of information, and there are always uncertainties in requirements. Investigation and validation are part of the knowledge-creation work in this space of complexity and uncertainties. Such rigorous work are documented in order to capture the rationale behind each design choice, which is often more valuable than the resulting artefact or solution itself in terms of future improvements or corrections.

> *But the messy side of the requirement is that, how do you know that requirements actually addresses the needs of your target goal? You don't … How do you make sure that YOUR requirements are valid? Anybody can come up with a requirement like, I need a car that drives a hundred kilometers an hour. Why? Do you need a truck? If this car happens to be a cargo truck, did you really need to drive that fast all the time? … if it were a truck drives a 100 kilometers an hour, or go from zero to a hundred in like six seconds… Wouldn't that be nice. But is it useful? Proper for a truck? A sportscar yes. So that has to factor into validating that use case. Where did that use case coming from? Is it legitimate? And you have to quantify that… So it implies that the information is there … Verifying would be the latter step, it's when we do the testing, we verify that the test results satisfies the requirement…*
>
> *… I experienced this one case where when we look at [the] test results come out and it pointed to, there is a mistake, we think, like a Typo in the requirements. Well, we literally have to spend hours doing a full audit of how did that number get into the documents in the first place. Everything is tracked so that we can track but every changes has to be reviewed and signed off for by multiple people. … So if we claim that [something] is a mistake, we have to prove that is a mistake… based on our knowledge of and the goal that we wanted to achieve, we know that definitely the number was not right…*
>
> *[In another situation] one of the first tasks that I had to do was … to provide the evidence for [the changes I recommended], then write up. And that needs to be up for scrutiny. Somebody else has to review it and agree with what my finding is. So basically [what] I did is an investigative job. You have to provide the* ***reasoning*** *[even for] why [the initial errors] didn't get caught [in] the [project] process. So it's not just the person [who might be] making the mistake, the reviewer would have to say, what is the most likely scenario that explains potential error [and still remain open to the idea that it] might not be error, it could be my mistake, or OUR mistake [in deeming something as an error]. So even though you have a gut feeling that [there] is a mistake there, you have to go in with a detective [mindset] and say, is that really a mistake? Or is some other property, might be pointing to some other problem downstream as well. It requires a lot of analytical sort of technique and analysis to make sure that you're not jumping to the conclusion, even though it's very tempting to just go with the obvious.* (Bee)

Appendix III. Unused Excerpts

8 - Yeah. Well the unknown is … it's not a bad thing at all. And most things are unknown. You're often asked to do something and the person asking really can't articulate exactly what they want. They just know this is a pain point, fix it, here's an idea. [Instead of just doing as suggested] it was more important to understand why. 'That's your pain point, you recommended a suggestion, but that's from a place over there. Let us take that suggestion. Consider everything that we're doing and all the tools. As long as we understand what the problem is and what we're trying to solve, we can come back with something that will meet your needs, even if it's not exactly what you asked for.' … And then in that first iteration, the person who requested sees, 'Not exactly what I thought, but ***now that I see this'****, their brain lights up may say, 'Maybe we can do this, this, that.' Those initial* ***feedback*** *that you get with the first* ***iteration*** *of anything is like gold. You have to write down all of those* ***questions*** *because those all become design specifications for later. … it really starts to take form from but there's gotta be a lot of back and forth, a lot of communication and an understanding of the problem that we're trying to solve. (Cube)*

4 - Well, I mean we're a business, so for us to making money is a primary incentive. It's what allows us to continue doing what we do, keeps the lights on. You know, at the end of the day we have to pack boxes, ship them with invoices and that's what keeps the business going. That's a very operational, mechanical view of it. But at its simplest, that's, that's what's happening. Um, ***but what facilitates that****? That's where it becomes more abstract. That's when you get into the sales and the marketing worlds and all of these other things. But from an operational perspective, it boils down to if anything is impeding our ability to produce something, then that becomes a very high priority [to address]. Or if we see ways in which we can support people, like in sales or marketing to better sell then, if we can enable people to sell better … Then that also takes a priority. Internal optimizations and very important. They reduce, you know, inefficiencies and whatnot. (Cube)*