

Capitalizing on Surprise and Doubt in Design Experiences*

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In design learning and practice, feelings of surprise and doubt are ubiquitous due to the inherent nature of design as complex, ambiguous, and uncertain. For design learners, engaging in surprise and doubt in a productive manner may be a challenge. For design educators, it may also be challenging to scaffold learning environments that support learners in constructive ways when confronted with uncertainty. To support learners' development and educators' teaching practice, we introduce transformative learning theory and draw a connection to design activities through a lens of surprise and doubt. Transformative learning theory emphasizes students' engagement in critical reflection to challenge their beliefs and assumptions and formulate new ways of thinking and being. We use the context of a graduate learning course on design cognition to illustrate how transformative learning theory may be enacted as an approach for capitalizing on experiences of surprise and doubt. This paper contributes to design teaching and learning by providing a conceptual approach for productively engaging in students' experiences of surprise and doubt during design learning and practice.

Keywords: surprise; doubt; transformative learning; critical reflection; design experiences

1. Introduction

Uncertainty and ambiguity are hallmarks of design practice and expertise. When designing, students may react with feelings of surprise and doubt to situations of uncertainty and ambiguity, as they struggle with making meaning in the unknown. These reactions may be considered indicators of students' engagement in authentic design practice [1, 2], and therefore, design teachers can benefit from capitalizing on these experiences as resources for helping students learn to design. The capacity to operate under uncertainty and manage the ambiguities of multiple possible solutions may also be considered core attributes of the Engineer of 2020 [3]: flexible, agile, and resilient engineers able to work across multiple perspectives and deal effectively with complexity. While design research provides insight into the role of uncertainty and ambiguity in design activities, there is little support for helping teachers appropriately scaffold student learning through uncertainty, from which experiences of surprise and doubt can lead to meaningful learning and enhanced design outcomes.

In this paper, we situate surprise and doubt as emotional responses to the unexpected and uncertain nature of design activities [4]. We then reframe "surprise" and "doubt" as elements of meaningful design practice and learning. With this framing, we introduce transformative learning theory and draw a connection to design activities through a lens of surprise and doubt. To illustrate transformative learning and its applications to design activities, we discuss how three elements of transformative learning were enacted in a graduate course on design

cognition. Through transformative learning practices, we propose that design educators may capitalize upon opportunities for learning through surprise and doubt in design practice.

2. Situating surprise and doubt in design activities and experiences

Uncertainty and ambiguity are two hallmarks of design activity. In design, uncertainty is described as a lack of clarity regarding design tasks and goals [5, 6]: incomplete (underdetermined) specification of start and goal states, complex interrelated components with conflicting performance dynamics, and constraints that are situated (contextualized), subjective, and with negotiable and non-negotiable features. Sources of ambiguity emphasize the existence of more than one possible solution (versus a single right or wrong solution), and having many degrees of freedom [6, 7]. Others describe design as a process of balancing a desire to reduce ambiguity (convergent thinking) with a desire to embrace ambiguity (divergent thinking) [8]. From the viewpoint of groups of people working together on a design task, Bucciarelli's [9] ethnographic research illustrates how design is a social process of negotiation where ambiguities are revealed through the interaction among individual "object world ways of knowing".

As ubiquitous features of design activity and design knowing, uncertainty and ambiguity provide the conditions that set in play essential features of design practice—such as iteration [10], abductive reasoning [5], problem framing [11], and reflective practice [12]. For example, because design tasks lack

certainty and are poorly structured, iteration becomes a necessary design strategy of learning through design [13]. This shows up as iterative loops, cycles, and spirals in design process models [14, 15], and design thinking concepts such as “co-evolution” [16].

Because design problems are complex, open-ended, and underdetermined, problem framing is considered central to design practice [5]. Problem framing involves abductive reasoning, a conjectural mode of inquiry that seeks to generate knowledge—as compared to inductive and deductive modes of inquiry that seek to validate knowledge [17]. Locke, Golden-Biddle and Feldman [4] argue that *doubt* inspires abductive reasoning as an essential aspect of dealing with uncertainty and ambiguity. In design, doubt provides an “experiential signal” (4, p. 910) that flags a need to revisit, reconsider, and iterate one’s approach. Doubt triggers abductive inquiry where possibilities are generated, tested, and iterated on, until new ideas emerge that satisfy doubt [4]. Under conditions of uncertainty, Locke, Golden-Biddle and Feldman [4] argue that design practitioners need to “turn toward” and embrace doubt as enabling generative reasoning and creating life-long learning.

Schön [12] presents a compelling case that reflective practice is not a rare event but rather “the core of practice” (p. 69). Reflective practice is a form of inquiry for dealing with situations that are puzzling, uncertain, complex, and involve value conflicts [12, p. 39–40]. Reflective practice requires a willingness to experience an unexpected event—to “experience *surprise*, puzzlement, or confusion” [12, p. 68, emphasis added] of an uncertain or unique situation “in ways that produce a shift in a mode of analysis that surfaces critique, sensemaking, and further action” [12, p. 50]. This practice becomes a “reflective conversation with the situation’s back-talk” (p. 132)—a process of spiraling through stages of appreciation, action and re-appreciation that may prompt a change in understanding or yield new discoveries. Building from Schön’s conception of reflection-in-action [18], Grace and Maher [19] offer a meta-cognitive model of creative design that explicitly acknowledges “surprise” as a “process that notices when expectations are violated” (p. 6). In this way, surprises are sources for reformulating design goals and exploring features of highly novel designs [19, 20].

Students’ experiences with uncertainty and ambiguity in design endeavors may manifest as observable behaviors of surprise and doubt. Furthermore, we have shown how surprise and doubt are characterized as core to design thinking, practice, and learning. How might educators connect with students in the emotional space of surprise and doubt

to foster these emotions as part of learning and design? In the following section, we introduce the theory of transformative learning to ground our conceptual approach that connects surprise and doubt with an educative purpose.

3. Transformative learning

We adopt transformative learning theory as a lens for observing, interpreting, and understanding opportunities for learning when students experience surprise and doubt in design. As a learning theory, transformative learning provides concepts and models for exploring and connecting with design in unique ways.

Mezirow [21] defines transformative learning as “. . . learning that transforms problematic frames of reference—sets of fixed assumptions and expectations (habits of mind, meaning perspectives, mind-sets)—to make them more inclusive, discriminating, open, reflective, and emotionally able to change” (p. 58). Frames of reference create “habits of expectations” that focus, shape, and delimit the ways we interpret our experiences [22]. They can become problematic when they serve as habitual predispositions or implicit rules for interpreting and taking action, or when they provide the basis for an incomplete or distorted interpretation of reality. When our pre-existing habits of expectation are no longer functional for making sense of a situation, we may experience an anomaly or crisis in perspective—a *disorienting dilemma* [23]. A disorienting dilemma catalyzes critical reflection through a process of becoming critically aware of how and why one’s problematic frame of reference limits the way one perceives, understands, and feels about reality. When new interpretations challenge an entire habit of mind, this can result in perspective transformation. When a new interpretation is used to guide decision making or action, this becomes learning.

Three central qualities of transformative learning are particularly relevant for design practice: *critical reflection*, *discernment*, and *praxis*. Transformative learning emphasizes rational, cognitive processes in the context of *critical reflection* [24–26]. Critical reflection occurs by challenging the veracity or validity of one’s assumptions and belief systems. These belief systems are often uncritically acquired through socio-cultural assimilation from childhood or as unintentionally learned stereotypes, yet they remain functional for us as adults [22]. When a person encounters a circumstance that does not neatly fit into their belief system, this can render previously unexamined assumptions no longer functional. This triggers critical reflection into the origins, nature, and consequences of their belief

system, and sets in play the potential for a perspective transformation.

Transformative learning emphasizes the process of individuation through “reflecting on the psychic structures (ego, shadow, persona, collective unconscious. . .) that make up an individual’s identity” [27, p. 7]. Taylor [27] describes individuation as a life-long journey of coming to understand oneself, facilitating a sense of empowerment and confidence, a deeper understanding of one’s inner self, and a greater sense of personal responsibility. The primary means of achieving individuation is the practice of *discernment*—a contemplative practice that enables a person to become more sensitive to the still, small, figurative voice within themselves. Boyd & Myers [24] describe the practice of discernment as “contemplative insight, a personal illumination gained by putting things together and seeing them in their relational wholeness” (p. 274). By assuming the posture of a listener, this allows one to be open to receive “alternative expressions of meaning” (p. 277). By persisting in what one may be feeling, including discomfort or uneasiness, one remains open to discover meaning as situated in experience, and enters into an “open dialogue, a kind of ‘talking back’” with the situation (p. 277).

Transformative learning emphasizes Freire’s [28] concept of developing one’s “ontological vocation”. Ontological vocation is “a theory of existence that views people as subjects, not objects, who are constantly reflecting and acting on the transformation of their world, so it can become a more equitable place for all to live” [27, p. 8]. This takes place as *praxis*—a process of reflection and action upon the world in order to transform it [28, p. 51]. In this way, praxis is not something one develops, but rather something one pursues as a journey of becoming more fully human. This is a transformative journey of a person “as an uncompleted being conscious of their incompleteness” [28, p. 43], situated within how they exist in the world “with which and in which they find themselves” [28, p. 83], and with social transformation and personal transformation as potential emancipatory outcomes.

In the next section, we show how these qualities of transformative learning apply to design activities.

3.1 Applications to design activities

The process of transformative learning is very similar to the process of reflection-in-action [11]. During design activities, designers often encounter anomalies in the results they were intuitively expecting (i.e., disorienting dilemmas) (see [22, 29]). This kind of disorienting dilemma demands engaging *discernment* by ‘listening’ to the situation as a means for acknowledging and becoming more aware of feelings, often manifest as discomfort or

uneasiness. This kind of discernment is further characterized by an open dialogue—a kind of ‘talking back’—with the situation (see [24]). When designers engage in *critical reflection*, they question the appropriateness of their expectations (see [22, 29, 30]) as they reflect on their practice—and the knowing implicit in their actions—even while still engaged in the design activity [11]. This critical reflection allows them to make sense of the situation by unveiling the understandings and underlying perspectives that are implicit in their actions [11, 12]. These underlying perspectives—in the form of unquestioned assumptions, expectations or meanings—are made explicit, criticized, restructured, and then embodied in further action (see [22, 29, 30]). In the end, reflection-in-action, can be observed as designers become conscious of their situation, engage in dialogue with the situation, and choose to act on the situation to change it, thereby enacting a form of *praxis* (see [27]).

Designers may also engage in transformative learning as they use cognitive artifacts such as sketching and prototyping. These artifacts help designers imaginatively engage with images and symbols of *discernment* and engage in the phenomena of ‘reflective conversation’ with a design situation throughout the design process [31–34]. The cognitive artifacts used in design activities, like the images and symbols of discernment, do not have to be physical or mental pictures as images. This is partly because the object being designed does not yet exist and therefore there is no actual correspondence between the artifact and external reality [33].

Designers also take part in the transformative learning process through *praxis* as they negotiate different design approaches influenced by various design cultures and mindsets. For example, Sanders [35] defined and described the design space as bounded on opposite sides by two opposing cultures. The expert mindset understands design as done by experts for people whom they consider as subjects, users, and consumers. In this culture there is an obvious separation between the two and design approaches influenced by this mindset will reflect this separation. The participatory mindset understands design as done with people whom they value as co-creators in the design process. This culture sees people as the true experts based on their experience in their respective domains (e.g., living, learning, working, etc.) and design approaches actively engage people in and throughout the process. To move from one culture to the other is difficult but not impossible, requiring a significant transformation.

As shown in Fig. 1, we situate feelings of surprise and doubt in alignment with the initial elements of transformative learning characterized as “a disor-

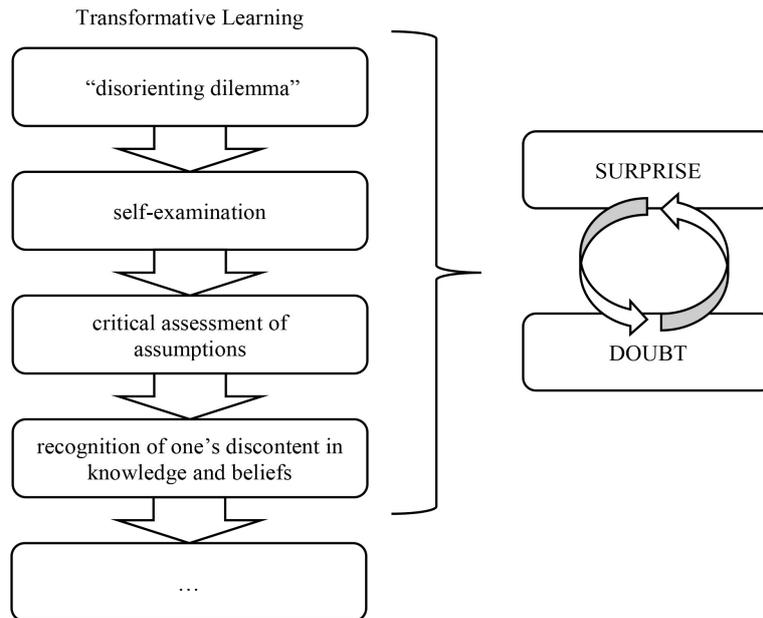


Fig. 1. Surprise and doubt represented as a cyclical form of initial phases of transformative learning [23].

ienting dilemma” and “self-examination” [23, p. 22]. As Mezirow [23] stated, “challenging one’s cherished beliefs (a leap into the unknown) often invokes a threatening emotional experience” (p. 24). In the context of design, the disorienting dilemma is brought upon by the inherent “wicked” nature of design problems [36] which instigate surprise and doubt in the face of ambiguity and uncertainty.

If a designer acknowledges feelings of surprise and doubt and is open to self-examination, then the designer can continue the transformative learning process by engaging in critical assessment of assumptions, recognition of one’s discontent in knowledge and beliefs, and other elements that lead to an exploration of options for change and action [23]. While we do not represent transformative learning as a theory with distinct stepwise phases, we have positioned surprise and doubt as inherent features of a “disorienting dilemma”. In this way, feelings of surprise and doubt may trigger engagement with transformative learning and become signposts for opportunities of transformative learning. In Fig. 1, the cyclical arrows between surprise and doubt represent engagement with surprise and doubt as a reflective ‘talk-back’ and simultaneous process—qualities inherent to the nature of *critical reflection* and *discernment*.

4. Connecting design and transformative learning through surprise and doubt

In the previous sections, we have presented feelings of surprise and doubt as an emotional response to

uncertainty and ambiguity that is core to design practice. We have also shown how qualities of transformative learning are evident within design, and how surprise and doubt may initiate opportunities for transformative learning. Based on these relationships, Fig. 2 illustrates the three contextual spaces of design, learning, and feelings of surprise and doubt. Here, we conceptualize surprise and doubt as a way to make meaning across the contextual spaces of design and transformative learning, as represented by the black two-way arrows in Fig. 2.

Translating transformative learning theory into the context of design education provides educators, practitioners, and researchers with a number of affordances. A key affordance is that transformative learning theory supports the development and identification of teaching practices that stimulate and help students resolve disorienting dilemmas associated with uncertainty and ambiguity. Learning environments informed by transformative learning theory foster opportunities to challenge students in critical reflection, discernment and praxis. This approach may expand the possibilities for students to intentionally and productively engage in surprise and doubt as part of the learning and design process—as opposed to avoiding, reducing, or controlling these feelings. In this way, experiences of surprise and doubt provide a bridge connecting design practice and transformative learning teaching practices. In the next section, we use an example of a graduate course on design cognition to illustrate elements of transformative learning theory and the applications to the teaching and learning of design.

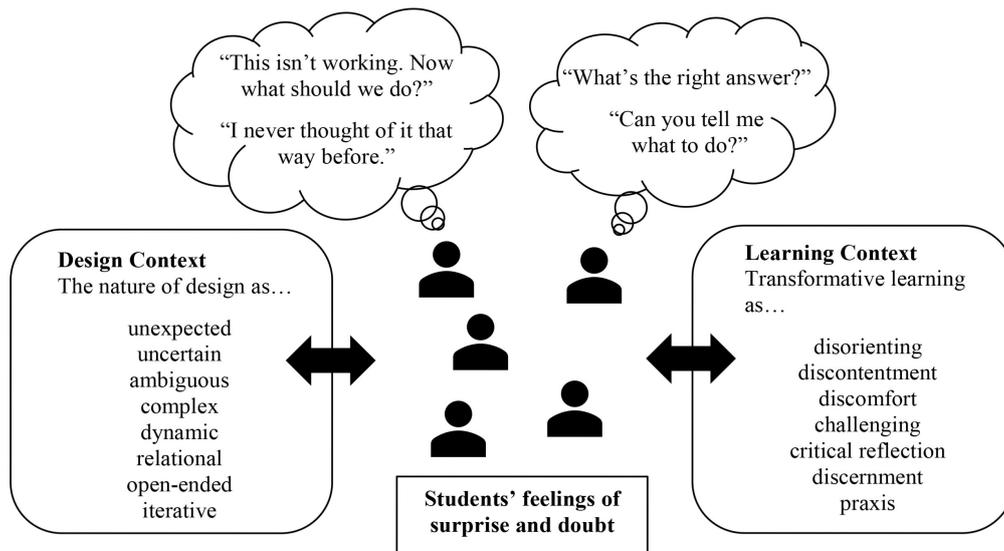


Fig. 2. The contexts of design and learning as situated interactions with students' feelings of surprise and doubt in design experiences.

5. Living in transformative learning: An example from a graduate course on design cognition

In this section, we explore the application and translation of transformative learning for design education through the use of a graduate course on design cognition. First, we re-conceptualize transformative learning as a distinct domain within the course. In this way, transformative learning may be intentionally enacted with its own unique learning objectives and outcomes for the course. We describe this enactment as "living in transformative learning" where transformative learning becomes an embodiment of pedagogical values, beliefs, and actions to inspire and guide learners towards their own agency and perspectives as design educators, researchers, and practitioners. In the graduate course, transformative learning theory was used to develop strategies for planning a gradual unfolding of students' experiences, and for scaffolding learning and development to achieve course outcomes. While we have situated this paper in the context of this graduate course, this example is not intended as a research case study with prescriptive procedures. Through the use of transformative learning as a conceptual approach, we aim to make sense of opportunities for learning in this course that connect with and capitalize on feelings of surprise and doubt in design. In the following sections, three elements of transformative learning salient to the graduate course are discussed: *empowerment*, *reflective discourse*, and *objective and subjective reframing* [23]. We describe the targeted practices used to address each of these transformative learning elements.

5.1 Empowering learners for agency and future oriented practice

In the context of design, design cognition, and design learning, the three core course learning objectives targeted students' ability to develop frameworks of understanding, translate research into practical applications, and to articulate their own view of design [37]. Where and how will learners enter into the conversation? What language, structure, and frameworks will help students engage and continue the conversation? The learning objectives of the course were conceptualized to explicitly embody qualities of transformative learning as a process of learning and as an intended outcome for learners to formulate their own articulations of design—that is, to develop a sense of agency as a designer with one's own beliefs, values, and dispositions. Mezirow [23] described a sense of agency as "the ability and disposition to become critically reflective of one's own assumptions as well as those of others, to engage fully and freely in discourse to validate one's beliefs, and effectively take reflective action to implement them" (p. 25). Therefore, students were encouraged to develop their own definition of design and no single definition was offered. This practice acknowledged the socially constructed nature of design and how different meanings may be negotiated among students in the course—thereby evoking practices of *discernment*. While the course recognized that students may enter with simple or narrow views about design theory, and many of the ideas presented in the course may be new, it was expected that the ideas would resonate with the students. Therefore, to support the process of meaning making about design, an emphasis was placed on providing a *language of*

design—as a means for students to talk about, think about, and organize design ideas and concepts.

One of the major course projects involved the formulation of a metaphor to conceptualize and describe design. This project, titled “Design as X” provided students with the opportunity to explore a perspective about design as a way to frame a personally meaningful approach to thinking about design. For example, students explore metaphors of design as social justice, empowerment, decision-making, transdisciplinary, transformative learning, human-centered, and sustainable. This project was an opportunity for students to bring in and share with others their own perspectives on design. Through this project, students were encouraged to seek new connections and challenge their current ways of thinking.

5.2 *Reflective discourse in design and learning conversations*

Reflective discourse refers to the use of dialogue to generate a common understanding. Mezirow [23] emphasized that “reflective discourse involves a critical assessment of assumptions” and “leads toward a clearer understanding by tapping collective experience to arrive at a tentative best judgment” (p. 11). In the graduate course, readings for each week were guided by a “big idea” and general overarching reflection prompts. Students engaged in reflective discourse through the personal reflection entries about the readings and through class discussion. Reflection questions focused on connecting and synthesizing ideas with prior experience (How do the readings connect to your own experience? How do the readings connect to ideas discussed in previous weeks?) as well as making meaning from feelings of surprise and doubt (What stood out to you as important, surprising, or provocative? What did you expect that you didn’t see? What aspects of the reading are you still struggling with, and why?).

In the class discussions, it was desirable to avoid “defining” concepts that may impose artificial limitations of understanding, or as an attempt to simplify complex concepts. Instead, as a way to acknowledge the fluid and open nature of the concepts, the development of conceptual frameworks was emphasized to acknowledge multiple ways of thinking. For example, one activity involved students to bring examples of design processes they use, have seen, or align with their practice. This activity allowed students to engage in different design process frameworks and to bring in different forms of knowledge in the classroom. In the course, learning through surprise and doubt meant challenging one’s beliefs, adopting different perspectives to explore multiple ideas, and engaging

in individual and collective reflective discourse to challenge and synthesize understanding.

5.3 *Developing and shaping frames of reference through objective and subjective reframing*

Transformative learning theory describes *frame of reference* as one’s perspective used to make meaning and interpret experiences [23]. As Mezirow [23] described, a frame of reference “selectively shapes and delimits perception, cognition, feelings, and disposition by predisposing our intentions, expectations, and purposes”, thereby providing the context for making meaning from experiences. In the graduate course, one of the goals of instruction was to inspire students to develop “purposively open” frames of reference—that is, meaning structures that have the ability to be flexible and dynamic while supporting a new exploration or understanding. In this way, frames of reference may serve as frameworks for understanding. For example, in the Design as X project, students were challenged to generate their own metaphor for design and articulate their own values about design.

Mezirow [23] describes *objective reframing* that “involves critical reflection on the assumptions of others” and *subjective reframing* that “involves critical self-reflection of one’s own assumptions” [23, p. 23]. An overarching strategy for the course was to acknowledge the different frames that students brought into the classroom. This approach served to identify students’ initial positions and to connect with existing structures as a way to orient and ground students’ future learning. To support the development of these frames of reference and engagement in objective and subjective reframing, the course was organized as a gradual unfolding of multiple layers of design with the course topics sequenced to become increasingly ambiguous, fluid, and broad. That is, the course started with the more familiar topics (e.g., design process) and became increasingly broad (adding exposure to multiple frameworks), increasingly subjective (encompassing more situated knowing as well as more subjective framings of design values), and increasingly more complex (acknowledging how the frameworks interconnect). The space of interconnection and relationships between frameworks was a place for students to form their own perspective within a much larger space of design theory. Developing and shaping frames of reference was also intentionally targeted through a team project that involved analyzing video and audio data of design review conversations. Teams were encouraged to identify topics of interest and analyze the video data from their own frames of reference. Through the project, team members negotiated their individual and collective frames of reference,

while experimenting with multiple frames of reference to interpret the data.

6. Discussion

The use of the graduate course as one example serves to illustrate possible opportunities and conceptual approaches for enacting transformative learning theory. Table 1 presents a summary of the three salient features of transformative learning in the graduate course with examples of corresponding transformative learning activities and learning opportunities for design in a broad context. This table shows how different practices and mechanisms for design and design learning may align with—and be supported by—a transformative learning approach. Through these practices, design educators may be positioned to identify and create moments of surprise and doubt as learning opportunities.

A transformative learning approach may also influence the teacher's role in the classroom—where the teacher becomes a facilitator, connector, and coach to challenge students in critical reflection and build scaffolded learning experiences. Although we have presented transformative learning in the context of a graduate course, teaching applications may be transferred to undergraduate design courses or capstone design experiences. Table 1 highlights conceptual ways design educators may connect transformative learning with their own teaching practice across broad contexts. For example, throughout the design process in a capstone course, surprise and doubt may serve as observable indicators of students engaging with ambiguity and uncertainty. As highlighted in Table 1, students may be *empowered* to become self-directed early in the design project through teaching appropriate methods for scoping a project, project management, and identifying their own learning needs for research. Students may engage in *reflective discourse* through

a design notebook or portfolio, iterative and collaborative team feedback, and formal and informal design review sessions. Students may continually shape their *frames of reference* as they gather information to challenge their assumptions, engage in problem framing and formulation, conduct tests and prototype their ideas, and incorporate feedback into redesign of their solutions.

7. Conclusion

As design educators, researchers, and practitioners, how can we continually search for surprise and doubt in learning? How can we be prepared to identify, embrace, and capitalize on surprise and doubt, as a launching point for transformative learning? We posit that leveraging surprise and doubt may be used as a pedagogical tool for engaging students in self-examination and self-discovery. In the graduate course, surprise was used to challenge students to reflectively turn inwards to consider their current position, beliefs, and values on design. We utilized an example of a graduate course in design cognition to highlight the ways that surprise and doubt could be evoked through transformative learning theory. We focused on three salient features of transformative learning—empowerment, reflective discourse, and objective and subjective reframing—as a way to translate transformative learning theory into teaching practices.

In this paper, transformative learning theory was used to ground an exploration into feelings of surprise and doubt as generative learning opportunities in design experiences. Future empirical research may consider students' level of performance and engagement with surprise and doubt throughout their design learning and understanding students' perspectives and behaviors when navigating through transformative learning. A transformative learning approach to pedagogy, course design,

Table 1. Three elements of transformative learning theory with corresponding activities and teaching opportunities in design practice

	Transformative learning as . . .	Learning opportunities in design through . . .
<i>Empowerment</i>	<ul style="list-style-type: none"> • Developing a sense of agency. • Using language and personal metaphors for meaning-making. 	<ul style="list-style-type: none"> • Student self-direction in project scoping and management. • Students identifying their own learning needs for research.
<i>Reflective discourse</i>	<ul style="list-style-type: none"> • Challenging assumptions. • Constructing conceptual frameworks for knowledge organization. 	<ul style="list-style-type: none"> • Design notebook or portfolio for students to capture, articulate and reformulate their learning through design. • Iterative team feedback and design review sessions to engage all students in reflection.
<i>Frames of reference</i>	<ul style="list-style-type: none"> • Acknowledging existing orientations. • Gradual unfolding of multiple layers of meaning and perspectives. 	<ul style="list-style-type: none"> • Team collaboration to challenge assumptions and positions of others. • Problem formulation and framing from multiple perspectives.

and curriculum theory may support new opportunities for student learning in design. We have described ways that transformative learning may be applied for planning, identifying and scaffolding experiences of surprise and doubt in design. Across broader contexts, future curriculum work and course design may consider how the qualities of transformative learning may become explicit course learning objectives to model a way of “living in transformative learning”. In addition, further research may explore connections between transformative learning and curriculum theory to integrate transformative learning theory with what it means to be an engineer capable of navigating uncertainty and ambiguity. Indeed, the Engineer of 2020 calls for engineers who are flexible, agile, and resilient [3]—for the future will be filled with surprise and doubt.

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