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Mapping the Relationship Between Critical Thinking and Design Thinking

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Abstract

Critical thinking has been a longstanding goal of education, while design thinking has gradually emerged as a popular method for supporting entrepreneurship, innovation, and problem solving in modern business. While some scholars have posited that design thinking may support critical thinking, empirical research examining the relationship between these two modes of thinking is lacking because their shared conceptual structure has not been articulated in detail and because they have remained siloed in practice. This essay maps eleven essential components of critical thinking to a variety of methods drawn from three popular design thinking frameworks. The mapping reveals that these seemingly unrelated modes of thinking share common features but also differ in important respects. A detailed comparison of the two modes of thinking suggests that design thinking methods have the potential to support and augment traditional critical thinking practices, and that design thinking frameworks could be modified to more explicitly incorporate critical thinking. The article concludes with a discussion of implications for the knowledge economy, and a research agenda for researchers, educators, and practitioners.

Keywords Critical thinking · Design thinking · Education · Entrepreneurship · Innovation · Knowledge economy

Introduction

Critical thinking skills are highly valued in higher education (Dym et al., 2005) and in today's competitive job market (Hogland-Smith, 2017; Levin, 2018; Montini, 2014; Reed, 2018). At the same time, graduates of design, engineering,

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entrepreneurship, and general business degree programs increasingly use design thinking methods to develop novel products, environments, services, and systems (Benson & Dresdow, 2014; Lancione & Clegg, 2015; Zidulka et al., 2018). Although these two modes of thinking are currently central areas of focus across many institutions in both higher education and in industry, they have evolved along largely independent lines and, as a result, they have not been explicitly integrated with one another. Based on a mapping an analytical comparison of the two modes, this paper argues that design thinking can offer educators creative new approaches to engaging students in critical thinking, and that critical thinking needs to be more explicitly integrated into product design and development methods.

Although scholars have argued that the cognitive processes associated with design can help students develop critical thinking skills (e.g., Razzouk & Schulte, 2012), critical thinking is generally not an explicitly discussed feature of the design thinking process. This is problematic because product design and development efforts can have significant adverse social, economic, and environmental impacts (Joyce & Paquin, 2016). High-profile product mishaps vividly illustrate the need for critical thinking in product development. Consider Microsoft's artificial intelligence (AI) Twitter bot, Tay, who posted "a deluge of incredibly racist messages… use[d] racial slurs, defende[ed] white-supremacist propaganda, and call[ed] for genocide" (see Price, 2016). Tay's unfortunate biases and reprehensible statements can be traced to at least two essential factors. First, despite defensive arguments to the contrary and despite their perceived autonomy, AI systems are *designed* systems: AIs like Tay may operate relatively independently once their initial algorithmic structure has been specified, but that algorithmic structure is initially defined by human beings. That is, an AI's intelligence is "parasitic" on the intelligence of its human creators (cf. Searle's 1980, 1983, and 1992 arguments concerning intentionality). Second, AIs like Tay are generally "trained" to define and calibrate their behavior by absorbing real-world collections (or "corpuses") of data—for example, actual human writing, speech, or images. Thus, the actions of AIs are not the actions of truly autonomous computational agents. On the contrary, their actions are fundamentally rooted in decisions made by human beings, and in the misguided values and biases that pervade human thought and discourse. The case of Tay illustrates that both businesses and society in general stand to benefit from a more explicit infusion of critical thinking into both the educational process, and into the product development methods that are used to drive innovation. A formal mapping between related aspects of critical thinking and design thinking could be used to guide empirical academic research programs that could, in turn, improve business practices in ways that support smart, sustainable, and inclusive growth (Carayannis & Rakhmatullin, 2014). In particular, such a mapping could support more resilient growth by supporting knowledge exchanges across the major pillars of university, industry, and civil society, consistent with innovation helix architectures (Carayannis & Rakhmatullin, 2014).

The present article aims to address this gap in the literature by providing a detailed preliminary mapping between (a) generally accepted components of critical thinking, and (b) widely used design thinking methods (Table 1). Definitions of both critical and design thinking remain the subject of lively debate (Halonen, 1995; Reine, 2017). The analysis presented in the present article is most closely aligned

Table 1 Mapping between critical thinking components and design thinking methods

CT component	CT component description (Hitchcock, 2018)	Banfield et al. (2015)	IDEO (2015)	LUMA (2012)
Observing	"One notices something in one's immediate environment"	Discovery Interview (p. 110) Test Your Prototype (p. 207) User Test Interview (p. 213)	Frame Your Design Challenge (p. 31) Peers Observing Peers (p. 60) Share Inspiring Stories (p. 78) Guided Tour (p. 64)	Fly-on-the-wall observation (p. 6) Contextual inquiry (p. 8) Walk a mile immersion (p. 9)
Feeling	"One feels puzzled or uncertain about something"			Journaling (p. 18)
Wondering	"One formulates a question to be addressed"	Problem Statement (p. 98) Question Formulation Technique (p. 94) Challenge Maps (p. 100)	Explore Your Hunch (p. 84)	Statement Starters (p. 50) Abstraction Laddering (p. 51)
Imagining	"One thinks of possible answers"	Idea Parking Lot (p. 78) Conduct a Pre-Mortem (p. 64)	Explore Your Hunch (p. 84)	Alternative worlds (p. 66) Problem Tree Analysis (p. 48) Statement Starters (p. 50)
Inferring	"One works out what would be the case if a possible answer were assumed"	8-Ups or Crazy Eights (p. 134)	Explore Your Hunch (p. 84)	Problem Tree Analysis (p. 48)
Knowledge	"One uses stored knowledge of the subject-matter to generate possible answers or to infer what would be expected on the assumption of a particular answer"	Review Research and Past Work (p. 86) User Journey Map (p. 112) Mind Map (p. 134) Review Assumptions (p. 170)	Define Your Audience (p. 44) Analogous Inspiration (p. 53) Download Your Learnings (p. 77) Share Inspiring Stories (p. 78)	Heuristic Review (p. 21) Schematic Diagramming (p. 69)
Experimenting	"One designs and carries out an experiment or a systematic observation to find out whether the results deduced from a possible answer will occur"	Design Sprint Test phase (p. 205) Decide on the Pre-Roll Questions (p. 200) Define the Tasks (p. 201)	Card Sort (p. 57) Explore Your Hunch (p. 84) Pilot (p. 146)	System Usability Scale (p. 26) Evaluative Research (p. 3) Think-Aloud Testing (p. 20)

Table 1 (continued)

CT component	CT component description (Hitchcock, 2018)	Banfield et al. (2015)	IDEO (2015)	LUMA (2012)
Consulting	"One finds a source of information, gets the information from the source, and makes a judgment on whether to accept it."	Discovery Interview (p. 110) Test Your Prototype (p. 207) User Test Interview (p. 213)	Recruiting Tools (p. 36) Secondary Research (p. 37) Interview (p. 39)	Contextual inquiry (p. 8) Walk a mile immersion (p. 9) Think-aloud Testing (p. 20–21)
Identifying and analyzing arguments	"One notices an argument and works out its structure and content as a preliminary to evaluating its strength."	Facts and Assumptions (p. 92) Challenge Maps (p. 100) Group Critique (p. 144) Identify Alternatives (p. 166)	Explore Your Hunch (p. 84) Brainstorm (p. 94) Bundle Ideas (p. 97)	Evaluative Research (p. 3) Think-Aloud Testing (p. 20) Critique (p. 24) Heuristic Review (p. 21)
Judging	"One makes a judgment on the basis of accumulated evidence and reasoning"	$100 Test/Risks (p. 164) 2×2 Matrix (p. 168) Ritual Dissent (p. 176) Idea Parking Lot (p. 78)	Get Feedback (p. 126) Define Success (p. 147)	Critique (p. 24) Rose, Thorn, Bud (p. 53)
Deciding	"One makes a decision on what to do or on what policy to adopt"	Converge phase (p. 157) Super Vote (p. 146)	Create a Project Plan (p. 34) How Might We (p. 85) Gut Check (p. 110) Determine What to Prototype (p. 111)	Bulls-eye Diagramming (p. 41) Importance/Difficulty Matrix (p. 43) Visualize the Vote (p. 46)

Critical thinking components and descriptions (Hitchcock, 2018) appear in columns 1 and 2, respectively, and selected examples of closely associated design thinking methods drawn from three popular design thinking frameworks (Banfield, Lombardo, & Wax, 2015; IDEO, 2015; LUMA, 2012) appear in columns 3–5

with action-oriented definition of critical thinking (e.g., Halonen, 1995: "the propensity and skills to engage in activity with reflective skepticism focused on deciding what to believe or do"), and with Brown's (2021) definition of design thinking ("a human-centered approach to innovation—anchored in understanding customer's needs, rapid prototyping, and generating creative ideas"). The article is structured as follows. First, eleven essential components of critical thinking (Hitchcock, 2018) are discussed in relation to specific design thinking methods, and for each component of critical thinking, examples of associated design thinking methods are discussed to elucidate the relationship between design thinking and critical thinking. In addition to providing an introduction to design thinking methods, the mapping and analysis reveal the shared conceptual structure of these two modes of thinking. Ultimately, it is argued that design thinking can be leveraged to develop creative new ways of engaging critical thinking in the classroom, and that critical thinking needs to be even more explicitly infused into the design thinking process. The mapping should serve as a practical reference for educators and practitioners who wish to explore ways of more explicitly integrating critical thinking and design thinking with one another. The article concludes with a discussion of some unique features of design thinking, an exploration of implications for the knowledge economy, and a research agenda to guide future design pedagogy and practice.

Critical Thinking

This section introduces influential definitions of critical thinking and concludes with an overview of the specific critical thinking framework used to develop the conceptual mapping advanced in the present article. Although critical thinking has been a longstanding and central goal of education (Hitchcock, 2018), there is no universally agreed upon definition of the term (Halonen, 1995) and its essential features remain the subject of debate (see Hitchcock, 2018, and Pithers & Soden, 2000 for reviews). Dewey's (1910) definition (of "reflective thinking") as "active, persistent and careful consideration of any belief or supposed form of knowledge in the light of the grounds that support it, and the further conclusions to which it tends" (Dewey, 1910, 1933, quoted in Hitchcock, 2018) remains influential to this day. However, since Dewey's time, a variety of definitions have been proposed (e.g., Ennis, 1987a, 1987b; Halonen, 1995; McPeck, 1981; Scriven & Paul, 1987). For example, McPeck (1981) defines critical thinking as "the appropriate use of reflective skepticism" (p. 19). Ennis' (1987a) definition emphasizes action: "reasonable reflecting thinking that is focused on deciding what to believe *and do* [emphasis added]" (p. 10). Scriven and Paul (1987) define critical thinking as "the intellectually disciplined process of actively and skillfully conceptualizing, applying, analyzing, synthesizing, and/or evaluating information gathered from, or generated by, observation, experience, reflection, reasoning, or communication, as a guide to belief *and action* [emphasis added]." Halonen (1995) argues that critical thinking scholarship is consistent with a hybrid definition: "the propensity and skills to engage in activity with reflective skepticism focused on deciding what to believe *or do* [emphasis added]."

Because design emphasizes applied problem solving, the mapping advanced in the present article is primarily based upon action-oriented definitions of critical thinking (e.g., Ennis, 1987a; Halonen, 1995; Scriven & Paul, 1987).

In addition to these general definitions, some scholars have also enumerated specific critical thinking abilities (Ennis, 1962, 1991; Glaser, 1941), skills (Facione, 1990; Halpern, 1998), and competencies (Fisher & Scriven, 1997). As with overarching definitions, numerous frameworks have been proposed and, as Hitchcock (2018) duly notes, "amalgamating these lists would produce a confusing and chaotic cornucopia of more than 50 possible educational objectives, with only partial overlap among them." For the purposes of the present article, it is necessary to identify some specific components of critical thinking that can be mapped to specific design thinking phases and activities. Therefore, this article examines how design thinking methods engage eleven generally accepted components of critical thinking identified and summarized by Hitchcock (2018): (1) observing, (2) feeling, (3) wondering, (4) imagining, (5) inferring, (6) knowledge, (7) experimenting, (8) consulting, (9) identifying and analyzing arguments, (10) judging, and (11) deciding.

Design Thinking

This section introduces and compares three prominent frameworks for design thinking that are used to develop the mapping advanced in the present article. Since Rowe (1987) introduced the term "Design Thinking," a variety of related frameworks and definitions of the term have been proposed (Cross et al., 1992; Beverland et al., 2015; Brown, 2021; Dorst, 2011; Luchs, 2016). As a result, there is no single, universally agreed-upon definition of design thinking (Reine, 2017). Dym et al. (2005) definition of "engineering design" summarizes the general concept of design thinking as it pertains to engineering education contexts:

> "a systematic, intelligent process in which designers generate, evaluate, and specify concepts for devices, systems, or processes whose form and function achieve client's objectives or users' needs while satisfying a specified set of constraints."

Because the present article focuses on applied design thinking frameworks that are currently widely used in business contexts, the specific activities and techniques discussed in the sections that follow are most closely aligned with Tim Brown's (2021) definition of design thinking as "a human-centered approach to innovation—anchored in understanding customer's needs, rapid prototyping, and generating creative ideas."

Although the three frameworks examined in this essay (Banfield et al., 2015; IDEO, 2015; LUMA, 2012) employ different terms for the main phases of the design thinking process, the underlying logic of the three frameworks is essentially the same. A "design sprint" proceeds through five phases (Banfield et al., 2015): (1) understand, (2) diverge, (3) converge, (4) prototype, and (5) test. Similarly, IDEO (2015) divides the design thinking process into three major phases: (1) inspiration, (2) ideation, and (3) implementation. LUMA (2012) also

advocates for a three-phase framework: (1) looking, (2) understanding, and (3) making. In essence, all three approaches advocate for a similar iterative sequence of activities. First, a diverse team—that includes but is not necessarily limited to designers—uses observational and information-gathering methods to empathize with a target audience, understand the challenges the audience may face, and become familiar with the contexts in which those challenges arise. In intermediate stages, divergent thinking and other creative ideation techniques are used to generate potential solutions. Next, convergent thinking (Cropley, 2006) methods are used to narrow the team's focus to a particular solution to test. In later stages, teams test their research-based assumptions and hypotheses regarding potential solutions by developing prototypes (e.g., digital or physical artifacts). These prototypes are used to conduct experiments and obtain feedback from current or prospective users. The resulting feedback is used to validate the team's original assumptions and hypotheses, and to inform improvements to the initial prototype. Finally, this sequence of design thinking activities can be repeated until a satisfactory solution to the original design problem is achieved.

As Johansson-Sköldberg and Woodilla (2013) note, "books, journals and the news media, and recently the popular press and semi-academic literature… [have] displayed a zeal for the concept as if 'design thinking' is a panacea for the economy." As a result—and for better or worse—design thinking has become the face of design (Kolko, 2018), and it is now widely regarded as a "gold standard" approach for creative product design across a variety of industries. Because design thinking is increasingly used to design the products we use, the environments we inhabit, and even the social interactions that we engage in, it is incumbent upon design scholars, educators, and practitioners to understand the relationship between critical thinking and design thinking. Identifying opportunities to more explicitly infuse critical thinking into the design process could help designers avoid or mitigate the kind of adverse outcomes exemplified by Microsoft's Tay.

Mapping Critical Thinking and Design Thinking

Mapping the relationship between critical thinking and design thinking is an important first step in understanding how these two important modes of thinking can more effectively integrated with one another. To this end, this section maps eleven essential components of critical thinking (Hitchcock, 2018) to specific design thinking methods drawn from three influential design thinking frameworks that are widely used in modern business (Banfield et al., 2015; IDEO, 2015; LUMA, 2012). In addition to the mapping itself (Table 1), illustrative examples of design thinking methods are examined in relation to critical thinking components. The mapping and analysis are informed by the author's experience as both a professional designer and design educator. The mapping and analysis suggest that design thinking methods have the potential to support and augment traditional critical thinking practices, and that

design thinking frameworks need to be modified to more explicitly incorporate critical thinking.

Observing

Both design thinking (Cross, 1993) and critical thinking (Yildrim & Özkahraman, 2011) have much in common with the scientific method, including their emphasis on the foundational role of observation. Hitchcock (2018) describes the *Observing* component of critical thinking as "notic[ing] something in one's immediate environment." For example, a classroom-based critical thinking activity might ask students to examine a museum's admission records to identify potential causes for historically low admission rates. Design thinking places a similar emphasis on the role of observation, but places an even stronger emphasis on close observation of "situated" (Brown et al., 2007; Suchman, 1987) human behaviors as they unfold in specific real-world contexts. For example, a design team tasked with improving the visitor experience for a museum might begin by reviewing the museum's admission records—as in the classroom-based critical thinking exercise example—but might also include observing and interacting with museum visitors (Banfield et al., 2015). During this initial observational stage, design team members might take field notes, conduct interviews, shadow museum goers, or observe how visitor behavior varies throughout the museum. These real-time observations can be collected using a variety of tangible or digital media, such as audio recordings, photos, or video, or by recording the paths that museum goers take as they explore. *Think-aloud Testing* (LUMA, 2012 p. 20–21) might be used to help the team understand an individual visitor's thought-process by asking the them to narrate their experience as they purchase admission, explore exhibits, or navigate the museum shop. Design thinking methods such as these can augment traditional approaches to teaching critical thinking by encouraging students to gather their own primary data in the field. The team's initial observations drawn from design thinking practices could serve as the basis for engaging the "feeling" component of critical thinking.

Feeling

The *Feeling* component of critical thinking is engaged in response to puzzlement or uncertainty (Hitchcock, 2018). In the design thinking process, feelings provide the impetus for observational activities or emerge in response to observations. Returning to the museum example, the design team might feel puzzled or uncertain as to why visitors are not exploring specific exhibits or even entire floors of the museum. When properly applied, design thinking methods can ground feelings in empathetic engagement both with other design team members, and with stakeholders outside of the design team. While there is much debate about whether empathy itself can be taught (Davis, 1990; Spiro, 1992), many design thinking methods are explicitly intended to promote empathetic thinking (e.g., see Banfield et al., 2015, p. 34). For example, *Personas* (Banfield et al., 2015 p. 108; LUMA, 2012, p. 33) might

be used to help the design team build empathy with a specific group or sub-group of museum visitors by asking participants to develop research-based summaries of emotions that the group has expressed during interviews. Personas are often supplemented with *Empathy Maps* (Gibbons, 2018), or diagrams that summarize an individual's (or group's) typical utterances, thoughts, feelings, and actions. *Journaling* (LUMA, 2012, p. 18) activities might be used to engage both design team members and museum visitors in critical reflection (Wells, 2013) and metacognition (Kuiper, 2002). These and other related design thinking methods can provide the raw material for fueling additional rounds of observation and feeling. Design thinking activities such as these may be useful for educators who wish to experiment with creative yet highly structured ways of asking students to empathetically engage with specific groups of people.

Wondering

Feeling often leads naturally to wondering. The wondering component of critical thinking is engaged when questions are formulated (Hitchcock, 2018), and wondering is an essential element in many design thinking phases and methods. Although questions are typically generated throughout the design thinking process, some design thinking methods are explicitly designed to elicit questions and curiosity among participants. During *wondering* phases of a design sprint, the design team may be explicitly required to formulate questions that begin with the phrase "*How might we*" (HMW; Banfield et al., 2015, p. 102). For example, museum staff and the design team might wonder, "Why aren't people signing up for the museum's mailing list?" This initial "why" question encourages participants to consider the underlying reasons that people are not signing up for the mailing list. To shift the team's focus from causes to generating ideas for potential solutions, this "why" question can be rephrased as an HMW question, such as "*How might we* reimagine the visitor experience so that members are aware of upcoming events?" The open-ended character of this HMW question is explicitly intended to encourage imaginative proposals for potential solutions. This aspect of design thinking is ripe for more explicit infusion of critical thinking practices. For example, design thinking exercises are generally not explicitly designed to ask participants to wonder about the potential implications of specific design decisions for underserved or potentially vulnerable populations.

Imagining

Because creative and critical thinking are closely related (Bailin, 1987, 1988), it is perhaps unsurprising that both design thinking and critical thinking acknowledge a central role for imagination. The *Imagining* component of critical thinking is engaged when possible answers to a question (or solutions to a problem) are generated (Hitchcock, 2018), and is most closely associated with the Diverge (Banfield et al., 2015), Ideation (IDEO, 2015), and Making (LUMA, 2012) phases in design thinking. These phases are generally designed to promote "divergent thinking," or the generation of a wide variety of disparate ideas (Colzato et al.,

2017; Hu et al., 2018; Runco, 1991; Runco & Acar, 2012; Sun et al., 2016). Design thinking exercises are based on the observation that imaginative or divergent thinking tends to flourish when there is a non-judgmental atmosphere within a team because harsh judgments can adversely impact a team's confidence and shut down ideas unnecessarily (Banfield et al., 2015). As Banfield et al. (2015) note, the Diverge stage typically includes collaborative brainstorming and sketching activities that encourage team members to generate a range of potential solutions to a design problem. For example, using *8-Ups* or *Crazy Eights* (Banfield et al., 2015, p. 134), team members might sketch various (at least eight) potential solutions to the foregoing HMW question ("*How might we* reimagine the visitor experience so that members are aware of upcoming events?"). In order to help promote a non-judgmental atmosphere, negative criticism is often explicitly (albeit temporarily) prohibited, and team members may be required to use the phrase "*yes, and…*" (a phrase derived from improvisational comedy; see Crossan, 1998; Moshavi, 2001) instead of "*yes, but…*" when responding to ideas offered by colleagues. The use of "*yes, and…*" can encourage group creativity by ensuring that team members do prematurely rule out ideas, or risk hurting a team member's feelings by focusing on reasons why an idea would not work. For example, after completing the *8-Ups* or *Crazy Eights* exercise, each team member may be given an equal amount of time to share their sketches while the non-judgmental "*yes, and…*" rule remains in effect. Because each team member is assured an opportunity to share their work, this type of activity has the potential to support more equitable teaching practices in classroom contexts by ensuring that all students' voices are heard. Similarly, an *Idea Parking Lot*, a specially reserved section of a whiteboard or flip-chart (Banfield et al., 2015) is often used throughout a design sprint to capture ideas without evaluating them in the moment. This emphasis on temporarily suspending judgment of the teams' ideas finds clear parallels in Hitchcock's (2018) emphasis on willingness to suspend judgment as an important "initiating disposition" for critical thinking.

While critical thinking generally treats imagining as an individual intellectual enterprise, design thinking generally treats imagining as a collaborative physical enterprise. Design thinking's *imagining* techniques are designed to encourage *both* individual and team-based artifact creation (e.g., prototyping), as well as engagement in physical activities (e.g., "body storming" or "embodied storming"; Schleicher et al., 2010), and this embodied action plays a valuable role in the design process (Haupt, 2015, 2018; Hu et al., 2018)—in particular, embodied action can support divergent thinking (Hu et al., 2018). A critical thinking activity might ask individual students to write a report in which they analyze the museum's admission records and building layout to identify potential improvements to the building's signage. In addition to encouraging a similar analysis, design thinking activities might also include shadowing (i.e., physically following and observing) museum visitors and capturing records of the specific routes that visitors take through the museum. Later, design team members might take turns walking these routes while noting imaginative ideas for improving museum signage along the way. In sum, design thinking can extend traditional critical

thinking activities by asking participants to create tangible artifacts, physically explore real environments, and strategically suspend judgment of each other's ideas.

Inferring

The *Inferring* component of critical thinking is engaged when one determines the logical consequences of assuming that a particular answer to question is correct (Hitchcock, 2018). For example, a critical thinking activity might ask students to think through the implications of incorporating automated registration kiosks into the museum's admission process. In contrast, a design thinking approach would emphasize creating "prototypes" (p. 183), or artifacts that the team can use to *test* (p. 205) the viability and usability of their proposed registration kiosk designs. As previously discussed, *Crazy Eights* or *8-Ups* (p. 134) asks participants to generate ideas for potential solutions to a design problem, and these solutions represent inferences or hypotheses regarding human wants or needs. In LUMA's framework (2012), *Problem Tree Analysis* (p. 48) encourages exploring causes and effects. In IDEO's (2015) framework, the *Explore Your Hunch* (p. 84) activity engages team members in hypothesis formulation and encourages participants to explicitly identify evidence that would support their hypotheses. Thus, as in the scientific method, team members are encouraged to work out in advance the sort of data that would support (or fail to support) their hypotheses. However, it is important to note here that although critical thinking may occur during inferential stages of the design thinking process, critical thinking is not an explicitly identified feature of the three design thinking frameworks discussed in this article. While recent frameworks such as Joyce and Paquin's (2016) "triple-layered business model canvas" (a design thinking-style activity that asks participants to consider the economic, environmental, and social implications of business models) represent a necessary and encouraging step toward integrating critical thinking into the innovation process, design thinking activities generally do not ask designers to critically evaluate the potential broader impacts and externalities of their designs. Thus, traditional critical thinking practices have the potential to enhance the inferential activities included in modern design thinking frameworks.

Knowledge

The *Knowledge* component of critical thinking is engaged when one relies upon their prior knowledge to formulate potential answers to a question or to determine the logical consequences of assuming a specific answer (Hitchcock, 2018). A critical thinking activity might ask students to rely upon their own knowledge and analysis of the museum's admission records to formulate proposals for improving the admission process. Design often promotes identifying knowledge gaps or known unknowns (Banfield et al., 2015, p. 92). For example, the team might review the museum's admission and exhibit records to identify categories

of information that are missing but that might be useful for the museum to collect in the future. For example, the team may notice that the museum has collected data on overall attendance on specific dates, but does not have historical attendance data for specific exhibits. This type of gap in the client's or team's knowledge often suggests specific experiments that the team should conduct in order to fill the gap.

In design thinking, team members might use *Heuristic Reviews* (LUMA, 2012, p. 21)—a technique closely related to *Expert Reviews* (see Harley, 2018)—to evaluate potential designs for the museum's website based on their knowledge of established best practices in web design, and based on the results of empathy-building techniques (see "Feeling" above). These evaluations might suggest inferences regarding which design is most likely to increase visitor attendance and engagement in an upcoming exhibit. Thus, *Heuristic Reviews* exemplify how traditional critical thinking practices can be extended to explicitly incorporate structured empathetic and perspective-taking practices drawn from design thinking.

Experimenting

The *Experimenting* component of critical thinking is engaged when one conducts an experiment in order to test one or more hypotheses (Hitchcock, 2018). A clear parallel is found in design thinking, which focuses on testing the viability of a wide range of novel solutions (Banfield et al., 2015). Experimenting is most closely associated with design thinking phases focused on prototype testing (e.g., Phase 5: Test, p. 205). During prototyping phases, teams develop artifacts (e.g., landing pages, paper prototypes, concept posters, cardboard mockups) that can serve as props for supporting conversations with users or customers. For example, the design team might build a full-scale mockup of a visitor registration kiosk using simple materials (e.g., cardboard or painted plywood) and hand-drawn mock-ups of the interactive screens that a kiosk could display. This prototype kiosk could be temporarily stationed at the museum's entrance and—to test the viability and usability of a new automated visitor registration process—visitors could be invited to tap on the paper "screens" while the team solicits a visitor's feedback on whether the new design is easy to use, which galleries the participant has visited in the past, and which galleries they are planning to visit today. In the context of traditional approaches to teaching critical thinking, experimentation is perhaps most closely associated with fields such as chemistry or physics, in which students are routinely asked to conduct experiments in order to test hypotheses. As a result, design thinking may offer some creative ideas to educators in other fields. For example, a political science course in which students use secondary research to support their arguments for several alternative public policy proposals could also develop prototypes of government websites that explain each of the policies, present those website mockups to stakeholders in the relevant community, and use the resulting feedback to support their policy recommendations.

Consulting

The *Consulting* component of critical thinking is engaged when one obtains information from an appropriate source, and decides whether or not to accept that information (Hitchcock, 2018). While traditional critical thinking frameworks tend to emphasize consulting relatively static sources of existing information (e.g., historical records, established texts, recent articles), design thinking encourages consulting *both* static and dynamic sources of information, placing special emphasis on multisensory (e.g., visual, auditory, haptic) information that can be obtained through interactions with real people in real-world contexts (Banfield et al., 2015). For example, by immersing themselves (see *Immersion* in Banfield et al., 2015, p. 52) in the museum over a period of several days or weeks, the design team can obtain a larger quantity of more accurate insights about visitor behavior than they would if they relied on only static sources of information, such as the museum's admission records alone. For example, a visit to the museum might reveal that noise levels are so high near the registration desks that some prospective visitors leave before completing the registration process. Thus, design thinking can potentially augment traditional approaches to teaching critical thinking by encouraging students to gather multisensory data through immersive, field-based research activities in real-world contexts.

Identifying and Analyzing Arguments

After consulting information sources, teams must inevitably make judgments regarding whether to accept the information, and this requires identifying and analyzing arguments. The *Identifying and Analyzing Arguments* component of critical thinking is engaged when one identifies the content and structure of an argument, and evaluates its strength (Hitchcock, 2018). For example, a critical thinking activity might ask students to identify and analyze arguments for potential improvements to the museum's admission process by writing an analytical essay or by engaging in a live debate during class. In general, design thinking activities are designed to be highly collaborative and are therefore likely to emphasize a group activity (e.g., debate) over individual activity (e.g., an essay or report). In design thinking, a *challenge map* (Banfield et al., p. 100) encourages a team to identify arguments by asking "why?" (e.g., "why should we do this?") in response to "*how might we…*?" (HMW) questions. For example, in response to the HMW question ("*How might we reimagine the visitor experience so that members are aware of upcoming events?*"), the team might ask, "Why should we reimagine the visitor experience?" Potential responses might include obvious, client-focused benefits ("to increase the museum's revenue"), or broader impacts on society ("to increase public appreciation of art"). These arguments themselves can then be subjected to further rounds of scrutiny and debate in order to identify underlying assumptions—an area where more explicit integration of critical thinking practices into design processes would be extremely valuable.

Judging

The *Judging* component of critical thinking is engaged when evidence and reason are used to evaluate something (Hitchcock, 2018). As previously discussed, critical thinking activities may rely upon historical data (e.g., admission records) to support judgments and evaluations, and students may be asked to support their individual or collective evaluations on the basis of primarily static and established sources of evidence. Judging is most closely associated with convergent phases of the design thinking process in which team members work together to evaluate ideas and decide on one or more ideas to pursue, develop, or implement. The ability to make judgments while iteratively progressing from concepts to concrete design proposals is essential to the design decision-making processes (Aranda et al., 2019; Haupt, 2018). For example, the design team might use a *2×2 Matrix* (Banfield et al., 2015, p. 168) to prioritize ideas for new wayfinding aids (e.g., maps, signage, kiosks) based on relevant factors (e.g., potential impact on museum visitors) or constraints (e.g., the physical layout of museum corridors, or the museum's budget for improving signage). The team might use *Ritual Dissent* (p. 176) and *Critique* (LUMA, 2012, p. 24) to assess the relative merits of ideas in light of data gathered from other phases, or *Rose, Thorn, Bud* (LUMA, 2012, p. 53) to judge ideas as being positive, negative, or having potential. Once the team's ideas have been judged, the team must decide which ideas they will focus on during the next phase of the design process. In comparison to many other design thinking techniques, these specific design thinking exercises are highly consistent with critical thinking practices. Nevertheless, they would benefit from framing that more explicitly acknowledges the crucial role that critical thinking can play in the design process. At the same time, critical thinking activities may benefit from design thinking's emphasis on reserving dedicated times for divergent thinking (e.g., brainstorming) and convergent thinking (e.g., critical evaluation)—a practice that is designed to help team members manage the emotional vulnerability that is often associated with subjecting ideas to the team's scrutiny.

Deciding

The *Deciding* component of critical thinking is engaged when one makes a decision (Hitchcock, 2018). Students and professional designers alike often reach decisions through debate in small groups, a process that is vulnerable to "groupthink" (the tendency for a group's desire for consensus to override the desire to sufficiently evaluate alternatives; e.g., see Callaway & Esser, 1984; Janis, 1971, 1982, 2008; Park, 1990). While design thinking also emphasizes the value of small group decision-making, design thinking activities are generally designed to ensure that all team members have an equal voice and explicit vote in the decision-making process. For example, using *Super Vote* (Banfield et al., 2015, p. 146), a method for rapidly visualizing and reaching team consensus, team members "dot vote" on ideas by drawing a specified number of dots next to ideas that they either personally favor, or that meet specific criteria mutually agreed

upon by the entire team. Team members might also be encouraged to dot vote on each member's sheet of *8-Ups* or *Crazy Eights* (Banfield et al., 2015, p. 134; see Imagining section above), and discuss the outcome of the voting process. These design thinking activities represent creative ways for educations to engage the "deciding" component of critical thinking in the classroom. Moreover, these activities can encourage a "productive dialogue" (Lloyd, 2013) that is intended to ensure that team gives equal consideration to ideas from all team members and that all team members have an equal voice in the outcome of key phases of the design thinking process. Thus, design thinking activities such as these can be used to help educators expand their toolkit of "active learning" (Bonwell & Eison, 1991; Prince, 2004) activities that can be used to support equity in the classroom.

General Discussion

The foregoing analysis links critical thinking components to a wide variety of design thinking techniques and reveals several insights regarding the relationship between these two seemingly distinct modes of thinking.

First, it is evident that properly implemented design methods have the potential to engage students and design practitioners alike in many of the core components of critical thinking. This is especially noteworthy because explicit references to the concept of critical thinking are conspicuously absent from the various business-oriented design thinking frameworks analyzed in the present essay. Second, there are aspects of traditional approaches to teaching critical thinking that could be creatively augmented or improved up on by implementing specific design thinking techniques. Third, the distribution of design thinking methods with respect to critical thinking components varies across the three design thinking approaches examined, suggesting that the design thinking approaches analyzed here engage some critical thinking components to a greater degree than others. For example, in comparison to the Design Sprint (Banfield et al., 2015) framework, IDEO's (2015) design thinking framework provides a relatively larger number of techniques for *Deciding*. Fourth, the mapping strongly suggests that the relationship between design and critical thinking is not one-to-one; that is, while a given design thinking method may engage one or more critical thinking components, this does not guarantee that design thinking necessarily engages critical thinking, or that it engages critical thinking to high degree. Finally, it is important to note that despite their shared conceptual structure, critical and design thinking approaches have developed relatively independently and have yet to be explicitly integrated with one another. This is an unfortunate state of affairs given that design pervades nearly every aspect of modern life by shaping the objects, environments, and social interactions that humans engage in throughout their daily lives. Thus, it is vital that future research explore ways of more explicitly infusing critical thinking into applied design thinking frameworks.

In order to more explicitly integrate these two modes of thinking, it is equally important to articulate significant ways in which the two modes differ from one another. While the mapping in Table 1 focuses on similarities between the two modes of thinking, the next section summarizes some significant limitations of traditional approaches to critical thinking, and identifies broad ways in which design thinking can be used to supplement critical thinking.

Unique Features of Design Thinking

While critical thinking remains an essential pillar of education, the foregoing analysis also strongly suggests that existing approaches to teaching critical thinking are limited in several key respects. In comparison with design thinking activities, critical thinking exercises are generally individualistic, intellectual, context-independent, conceptual exercises; in contrast, design thinking exercises are generally more collaborative, embodied, and prospective in character. Inspired by recent developments in cognitive science (Hutchins, 1996, 2010; Suchman, 1987; Varela et al., 1991; Wilson, 2002) and by Razzouk and Shute's (2012) contention that design thinking "can potentially enhance the epistemological and ontological nature of schooling," this section briefly examines each of these claims in turn.

From Individualistic to Collaborative

Despite the popularity of group discussions in classroom contexts, critical thinking is commonly framed as a localized property of individuals rather than a sociocultural (Davies, 2015) or distributed cognitive activity of groups. As Dym et al. (2005) note, "the design process is itself a complex cognitive process," and in contrast to traditional critical thinking practices, design thinking practices distribute this cognitive process across the members of a collaborative team (see also Stempfle & Badke-Schaub, 2002). In this respect, design thinking promotes "collaborative learning" (defined as "grouping and pairing of students for the purpose of achieving an academic goal" by Gokhale, 1995, p. 22)—a form of learning that is commonly associated with critical thinking outcomes (Gokhale, 1995; Totten et al., 1991). Although design thinking sessions in industry settings are often facilitated, managed, or "owned" by design teams, proponents of design thinking advocate for incorporating real users into the process, providing opportunities for non-designers to engage in both design and critical thinking. In sum, design thinking can extend critical thinking beyond its traditional status as a localized property of loosely affiliated individuals to a distributed property of highly collaborative teams. This shift in focus is critically important as many scholars now forcefully argue that the vast majority of problems we face in business and society are in fact "wicked problems" (Churchman, 1967; Rittel & Weber, 1973) that can only be addressed by highly diverse transdisciplinary teams (Mason et al., 2018; Norris et al., 2016; Waddock, 2013).

From Intellectual to Embodied

Traditional approaches to critical thinking generally fail to acknowledge the epistemic (knowledge-generating) value of creating tangible artifacts, and of engaging in embodied (physical) activities. In contrast to critical thinking, design thinking places an equal emphasis on "critical making" (Somerson, Hermano, & Maeda, 2013), or the concretization of one's thoughts through making physical artifacts such as sketches or mockups made of cardboard. In addition, some design thinking activities such as "bodystorming" or "embodied storming" (Schleicher et al., 2010) require active, empathetic involvement of one's own body in the design process (see "Imagining"). For example, a design team might practice empathizing with the elderly by wearing specially designed suits that simulate relevant effects of the aging process. In design thinking, creating physical artifacts and reproducing observed behaviors actively involves team members in the learning process by encouraging them to concretize their ideas and empathize with others. Thus, design thinking activities are particularly well-suited to encouraging "active learning" (Bonwell & Eison, 1991; Prince, 2004) in the classroom. These activities have the potential to enhance and supplement the benefits of more traditional approaches to critical thinking, such as class discussions and analytical essays.

From Retrospective to Prospective

In general, traditional approaches to critical thinking emphasize retrospective observations based on established sources of information (e.g., books, articles, case studies). For example, a history course might ask students to examine historical records to understand causal factors contributing to a decline in public support for the arts. Although design thinking activities also often rely on established sources of information, they are fundamentally more prospective in nature because they ask participants to imagine possible futures in which a specific problem (e.g., low admission rates at a museum) is solved by implementing a concrete solution to that problem (e.g., a registration kiosk). This is not to say that either mode of thinking is better or more valuable than the other—only that the two modes of thinking have historically tended to emphasize different things. Prospective design thinking activities have the potential to help students reach the highest levels of Bloom et al. (1956) taxonomy of educational learning objectives and outcomes: *synthesis* (Bloom et al., 1956) and *creation* (Krathwohl, 2002). Because modern business problems demand that students not only analyze and criticize (abilities traditionally associated with critical thinking) but also synthesize and create (abilities strongly associated with design thinking), this represents an important area of overlap between the goals of higher education and modern business.

Implications for the Knowledge Economy

Design thinking methods are anything but static—businesses are constantly evolving and adapting design thinking methods to suit the unique considerations of specific industries, business processes, and business goals. Thanks to this already

widespread culture of process innovation, organizations can easily modify design thinking methods to more explicitly incorporate critical thinking practices that align with the goals of innovation helix perspectives, and that support the goals of smart, sustainable, and inclusive growth. For example, smart growth entails "more effective investments in education" (Carayannis & Rakhmatullin, 2014): because critical thinking underpins innovation (Brown, 2015), and because design thinking methods are so widely used in industry contexts, it is vital that future research have a guiding framework for empirically investigating the relationship between these two modes of thought; these future empirical investigations will constitute a much-needed investment in supporting the improvement of modern business education. Sustainable growth involves transitioning to a low-carbon economy, creating jobs, and reducing poverty (Carayannis & Rakhmatullin, 2014). Joyce and Paquin's (2016) "Tripled Layered Business Canvas" provides a concrete example of how the common practice of creating business model canvases during early-stage business planning can support responsible research and innovation (RRI; Owen et al., 2012; Lukovics et al., 2019) by encouraging business leaders to explicitly identify and critically evaluate possible environmental and social externalities—both positive and negative—associated with potential business models. In sum, future empirical research guided by the preliminary mapping advanced in this paper is vital to ensuring that entrepreneurs and innovators develop business models and business practices are, as Carayannis and Rakhmatullin (2014) highlight, "not only environmentally but also financially and socially sustainable."

Recommendations for Future Research

The mapping advanced in the present article suggests several valuable areas for future research. First, quantitative and qualitative methods should be used to empirically examine precisely how design thinking methods and frameworks can support critical thinking outcomes in the classroom and vice versa. The mapping provided in Table 1 should serve as a practical introductory guide for educators in a variety of fields to experiment with leveraging design thinking methods to creatively support critical thinking–focused learning objectives. For example, educators in the humanities or STEM may benefit from using design thinking methods (Aranda et al., 2019; Kelley & Sung, 2017) that can collaboratively engage core components of critical thinking. Second, given design thinking's strong connection to the field of service design and its emphasis on applied problem solving, service learning (Eyler & Giles, 1999), constructivist approaches (Scheer et al., 2012), and experiential learning in general (Kolb & Kolb, 2016; Zidulka & Mitchell, 2018) could provide a valuable foundation for carrying out this research, with strong potential for fostering critical and empathetic engagement among students and communities (Rosenberger, 2000). Third, although design thinking is typically led by knowledgeable facilitators, students could be trained to run their own design thinking sessions using approaches inspired by "peer-led team learning" (PLTL), an approach that has shown promise in supporting critical thinking outcomes in science education (Quitadamo et al., 2009). Fourth, because products are often designed to take advantage of human psychology in ways that do not always align with end users' interests (Nodder, 2013), more

explicit integration of critical thinking practices into design education would result in positive outcomes for society. For example, design thinking methods could be leveraged (or adapted) to engage students in critical thinking with respect to relevant professional ethics codes (e.g., see "ACM Code of Ethics and Professional Conduct," 2018) and with respect to the general ethical implications of their proposed design solutions. Such engagement may reduce the likelihood of students engaging in ethically questionable practices in their academic and professional work.

Finally, it is important to note that although design thinking and critical thinking share a great deal in common, the three design thinking frameworks examined here are not explicitly designed to integrate critical thinking practices. Thus, design thinking would benefit from more explicit integration of critical thinking. Tools such as Joyce and Paquin's (2016) "triple layered business model canvas"—which extends Osterwalder and Pigneur's (2010) business model canvas to account for a product's environmental lifecycle and societal implications—provide an instructive example of how collaborative brainstorming methods can be extended to anticipate broader environmental and social impacts.

Limitations

There are several obvious criticisms of the arguments advanced in this essay. First, the proposed mapping between critical thinking components and design thinking methods may be taken to imply that merely implementing a particular design thinking method necessarily guarantees engagement of associated critical thinking components. However, the mapping should not be interpreted as promoting a necessarily causal relationship between these two modes of thinking. Whether a design thinking method actually engages an associated critical thinking component depends on a variety of factors that apply equally to any professional or pedagogical situation. These factors include—to say nothing of broader physical, social, and environment factors—the competency of the facilitator and the willingness of participants to faithfully engage in the process. In this sense, design thinking methods are no different than any other activity or method for promoting critical thinking. Second while, the mapping advanced here establishes that these two modes of thinking share common elements, the arguments in this essay should not be confused with the dubious notion that design thinking fully encompasses critical thinking. As previously discussed (see "Observing"), although critical thinking and design thinking share a great deal in common, they differ in important ways, and each approach offers unique advantages. Rather than supplanting, encompassing, or co-opting critical thinking, design thinking represents a useful applied framework for engaging both students and working professionals in essential components of critical thinking.

Conclusion

While professional organizations and scholars have suggested that design thinking has the potential to engage critical thinking (e.g., see ITEA, 2017; Razzouk & Schulte, 2012), design and critical thinking methods have evolved independently;

as a result, the relationship between these two modes of thinking has remained unclear. Clarifying the relationship between these two modes of thinking could help educators leverage design thinking methods to support and augment traditional approaches to critical thinking in the classroom, and help working professionals more explicitly integrate critical thinking practices into the design process. The present article clarifies the relationship between these two modes of thinking by mapping essential critical thinking components to specific design thinking methods. The mapping reveals that although the two modes of thinking share much in common, they also differ in several notable respects. The mapping also suggests that design thinking can be leveraged to engage specific components of critical thinking in the classroom, and that critical thinking could be more explicitly infused into the design thinking process. In particular—and in contrast to traditional approaches to critical thinking—design thinking generally engages participants in more collaborative, embodied, and prospective activities. Thus, design thinking methods have the potential to not only engage but also augment traditional approaches to teaching critical thinking. At the same time, critical thinking needs to be more explicitly integrated into the design thinking process in order to ensure that design efforts maximize potential benefits and minimize potential harms to society. Future discourse and empirical research examining the relationship between these two influential modes of thinking is vitally important to design pedagogy and practices. The mapping and analysis advanced in the present article provide a necessary foundation for supporting future empirical work examining the role of design thinking in innovation, entrepreneurship, and business education.

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