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Demystifying the Genius of Entrepreneurship: How Design Cognition Can Help Create the Next Generation of Entrepreneurs

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DEMYSTIFYING THE GENIUS OF ENTREPRENEURSHIP: HOW DESIGN COGNITION CAN HELP CREATE THE NEXT GENERATION OF ENTREPRENEURS

ABSTRACT

Entrepreneurship education is a key beneficiary of design thinking's recent momentum. Both designers and entrepreneurs create opportunities for innovation in products, services, processes, and business models. More specifically, both design thinking and entrepreneurship education encourage individuals to look at the world with fresh eyes, create hypotheses to explain their surroundings and desired futures, and adopt cognitive acts to reduce the psychological uncertainty associated with ambiguous situations. In this article, we illustrate how we train students to apply four well-established cognitive acts from the design cognition research paradigm—framing, analogical reasoning, abductive reasoning, and mental simulation—to opportunity creation. Our pedagogical approach is based on scholarship in design cognition that emphasizes creating preferred situations from existing ones rather than applying a defined set of tools from management scholarship. In doing so, we provide avenues for further development of entrepreneurship education, particularly the integration of design cognition.

1. INTRODUCTION

As universities around the world have incorporated entrepreneurship education (Oxford, 2013), scholars and entrepreneurs alike have grown increasingly skeptical of the usefulness of traditional teaching methods, which rely on business plans, case studies, and guest speakers (Gartner & Vesper, 1994; O'Connor, 2013; Vesper & Gartner, 1997; Williams Middleton & Donnellon, 2014). After all, entrepreneurs (Busenitz & Barney, 1997; Dyer, Gregersen, & Christensen, 2008; Sarasvathy, 2001) think very differently from managers and the rest of the population. The ill-defined nature of entrepreneurial problems contradicts students' expectations of well-defined processes aimed at reaching a single answer with significant guidance from instructors (Austen, 2012).

In response, many business schools, and even entrepreneurial programs, are adopting design thinking techniques and tools. To strengthen students' understanding of these design thinking tools, we claim that teachers should emphasize their cognitive underpinnings. A lucid comment from one of our students about customer journey maps supports our assertion. The student commented that "due to the complex and personal nature of decision-making, it is not always possible to map an experience as a set of linear, cause-and-effect steps. Doing so results in only a partial understanding of the journey, with no consideration of the user's context and past experiences." At the end of the course, he offered the following reflection. "By supplementing these tools with additional cognitive activities, such as framing and abductive reasoning, we gain a deeper appreciation of not only what the user is feeling, but why they are feeling that way. Ultimately, this allows us to comprehend the root cause of the user's frustrations, but also leads to a broader understanding of the problem. It is this broader understanding at a higher level of abstraction that leads to genuine and impacting innovation."[1]

This article extends recent contributions to entrepreneurship scholarship (Glen, Suciu, & Baughn, 2014; Van Burg & Romme, 2014) to explicate how design thinking, defined as the cognition, processes, and tools designers use to imagine a desired future, informs the process and skills needed to spot and develop opportunities (Garbuio & Lovallo, 2015). Specifically, we respond to Glen et al.'s (2014) call to incorporate design thinking in entrepreneurship education in a way that complements, rather than replaces, the analytical tools and teaching styles of most business schools. To do this, we expand on a stream of design thinking scholarship (Johansson-Sköldberg, Woodilla, & Çetinkaya, 2013) that advocates consideration of the cognition that underlies design thinking methods. Analytical reasoning, the typical mode of reasoning taught in business schools, equips students with cognitive skills and technical methods to deal with varying degrees of uncertainty; however, there is a gap in management education when it comes to addressing complex, ill-defined problems with scarce or ambiguous facts and unclear means-end relationships (Schön, 1983). Design cognition addresses these gaps by identifying specific cognitive acts and structures associated with productive outcomes to open-ended and unstructured situations.

Four recent and convergent developments support the need for a more nuanced understanding of the contribution of design cognition to entrepreneurship education: (1) opportunity creation as a cognitive skill, (2) the fact that opportunities are created rather than discovered, (3) the popularity of lean start-up approaches (which further exemplifies the practical resolution of the debate between opportunity discovery and creation), and (4) design thinking as a cognitive rather than process-based construct.

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[1] Massimo Garbuio thanks Rob Dongas for this reflection.

First, the entrepreneurial field increasingly acknowledges that opportunities emerge from cognitive skills (Baron, 2004, 2006; Baron & Shane, 2007; McGrath & MacMillan, 2000) that can be developed and enhanced through education (DeTienne & Chandler, 2004; Fiet, 2002; Muñoz, Mosey, & Binks, 2011). Design cognition scholarship provides a well-researched and teachable set of cognitive acts, including convergent and divergent thinking, framing, analogical reasoning, pattern recognition, counterfactual thinking, mental simulation, and abductive reasoning (Baron, 2004; Cornelissen & Clarke, 2010; Gaglio, 2004; Grégoire, Cornelissen, Dimov, & Burg, 2015; Mitchell et al., 2002). Yet many instructors do not know how these processes contribute to opportunity creation and how to effectively introduce students to these acts.

Second, the longstanding debate over whether opportunities are discovered or created (Alvarez & Barney, 2010) has been resolved, in practice rather than theory, by budding entrepreneurs' preference for methods that are compatible with creation rather than discovery. Specifically, older scholarship in entrepreneurship has explored how exogenous shocks to preexisting industries form opportunities, which unusually alert individuals or firms discover (Kirzner, 1989; Shane, 2003). Newer approaches instead lean toward the assumption that entrepreneurs themselves form opportunities endogenously through an enactment process (Aldrich & Ruef, 2006; Shane & Venkataraman, 2003). The difference has profound pedagogical implications. In the discovery approach, opportunities can be identified through typical tools of strategic analysis, such as evaluating threats and opportunities in the environment (Porter, 1980). The central features of the creation approach are a willingness to experiment and an ability to learn from experimentation (Alvarez & Barney, 2010). This learning requires creativity, mental flexibility, the ability to be open to conflicting feedback, and a willingness to fail and learn from experience. In contrast, the discovery approach draws on the techniques for strategic analysis for pedagogy; those teaching creation opportunities are inspired more by creative design and art (Baker & Nelson, 2005; Sarasvathy, 2001)

Third, the increasing pace and dynamism of business environments, in which entrepreneurs pitch their ideas, suggest that an extensive business plan is often not feasible. The lean start-up approaches taught as part of accelerators and incubators provide incentives for students to pitch both raw and well-formed ideas, refine them, and iterate until a commercially viable concept emerges. Accelerators, incubators, and online programs offer both brief and long courses on developing opportunities and business models, often filling the gap left by conventional entrepreneurship courses. For entrepreneurs, the frameworks and concepts of the lean start-up (Ries, 2011), the business model canvas (Osterwalder & Pigneur, 2010), the long-term value of customers, and the cost of acquiring a customer are far more commonly used than the strategic analysis tools introduced in early entrepreneurship education. Both lean start-up and the business model canvas approach refer to design thinking tools and processes, though they shy away from explicitly teaching the cognitive acts that facilitate the development of new opportunities.

Finally, as entrepreneurial scholarship has emphasized the cognitive aspects of opportunity creation, so has design thinking (in design studies scholarship) emerged as a cognitive rather than procedural construct (Visser, 2006, 2009). Teaching cognition rather than process has also emerged as a fundamental pedagogical perspective (Eastman, 1999; Oxman, 2004) in which the cognitive acts rather than the process of design comprise the explicit teaching content. Similarly, in a meta-analysis of creativity training, cognitive strategies have indeed been found to play a critical role in enhancing individuals' creative skills (Scott, Leritz, & Mumford, 2004). The role of the educator is to challenge students with questions that lead them to think differently about problems (Gómez Puente, van Eijck, & Jochems, 2013a; Gómez Puente, van Eijck, & Jochems, 2013b). Over the years, and across disciplines, as design thinking has evolved into different meanings, its foundations often have been taken for granted (Johansson-Sköldberg et al., 2013). A fundamental distinction can be made between the evolution of design thinking in the *design discourse* and in the *management discourse*. Some time ago, the research focus of design discourse shifted toward the discovery of cognitive skills, reflective practice, and the creation of meanings, among other aspects. Meanwhile, the latter has become popular through a narrower interest on (1) how designers work (Brown, 2008, 2009; Kelley, 2007), relying heavily on IDEO's way of working with innovation; (2) a way to approach organizational problems from a practical perspective (Dunne & Martin, 2006; Liedtka & Ogilvie, 2011; Martin, 2009); and (3) management theory, which views design thinking as an organizational resource leading to innovation (Collopy & Boland, 2004).

In this article, we adhere to design thinking rooted in the cognitive design discourse, which recommends that designers and educators nurture a set of cognitive skills rather than processes and tools. In the cognitive design research paradigm, design practice emanates from a set of cognitive acts and forms of knowledge representations associated with the parallel feat of creating a new object, service, or system and the way this new creation works (Dorst, 2011). The cognitive acts presented here are based on empirical research spanning over 60 years (Cross, 2007), which confirms that the choice of cognitive acts and the forms of knowledge representations determine the productivity of the designer and the quality of the solution. With this in mind, we are able to provide a clearer contribution to entrepreneurial education by building on the most current design discourse.

Next, we review current approaches to entrepreneurial education, expand on key emerging trends and show how design thinking and design cognition have reached both scholarship and practice. Then we briefly expose the four cognitive acts at the basis of design and entrepreneurial cognition and follow with a framework for a design-driven entrepreneurship education. We conclude with a discussion of applications of this approach and some final remarks.

2. ENTREPRENEURIAL EDUCATION: A ROAD PAVED BY DESIGN COGNITION

Over the years, entrepreneurship education has evolved dramatically in part due to influences from other fields. Table 1 summarizes key approaches and provides some considerations to contextualize our own approach.

Insert Table 1 about here

Initially, entrepreneurship education was shaped by the *planning school*, suggesting that opportunities are discovered through meticulous business-plan development and systematic search (Fiet, 2002; Herron & Sapienza, 1992). Over time, it became apparent that entrepreneurs themselves can create opportunities through an endogenous enactment process. Some examples include: the *contingency planning approach,* which emphasizes divergent thinking, a perspective that train entrepreneurs to better recognize opportunities through a process that unfolds over time; *opportunities-centered learning,* which focuses on exploration and development of opportunities through case studies; and, *effectual entrepreneurship*, which encourages entrepreneurs to develop goals based on personal strengths and available resources.

Entrepreneurship scholars and practitioners increasingly call for design thinking concepts and design methodologies to assist with entrepreneurship teaching and new venture creation more broadly (see, e.g., Glen et al., 2014; Van Burg & Romme, 2014). Design thinking has been identified as an efficient way of dealing with highly uncertain situations and uncovering unanticipated problems early (Fixson & Rao, 2014; Fixson & Read, 2012).

In the practice of entrepreneurship education, the lean start-up approach and the business model canvas practice both build on the management discourse of design thinking.

The *lean start-up approach* (Blank, 2013; Ries, 2011) incorporates aspects of the management discourse of design thinking. Stemming from quality improvement and engineering, lean methodology encourages entrepreneurs to focus on experimenting and getting feedback from potential customers for the next development iteration rather than following a rigid business plan. A lean start-up creates a “minimal viable product,” a product with the minimum features customers need so that it can be “pivoted” or changed along the way based upon feedback. Like the management discourse, it encourages iteration, but its focus on developing a functioning commercial prototype means that it devotes less time to broadly and deeply characterizing the problem and ideating on solutions, as design thinking emphasizes. It also assumes that the firm should validate hypotheses about product and feature desirability with users in the marketplace. This methodology has been widely adopted, especially by incubators and government agencies such as the U.S. National Science Foundation in its Innovation Corps program.[2]

Although the *business model canvas approach* is not derived from design thinking and involves setting up a different problem (i.e., the business model itself), it shares several characteristics with design thinking: a focus on identifying users’ needs, a cross-disciplinary view of the “business model” and its underlying value proposition (the product or service “design”), and significant collaborative work for ideating new business models. Accordingly, the business model canvas approach resembles design thinking’s phases as described in the management discourse of design thinking, and some of its tools, such as empathy maps and persona profiles (Johansson-Sköldberg et al., 2013).

In managerial scholarship, the concept of design thinking is rather equivocal, largely because design thinking has entered the field from design practice rather than from design scholarship. The tools and processes of design thinking brought into management practice—

[2] National Science Foundation (2013). New grants to Innovation Corps "Nodes" further enhance public-private partnership. http://www.nsf.gov/news/news_summ.jsp?cntn_id=127011 (Accessed Oct 1, 2015).

user-centricity, journey mapping, prototyping, and experimentation—differ from those prevalent in design scholarship and the focus of our study. Although the processes, techniques, and tools of design are indeed relevant to management, in design research, the object of study has turned toward the behaviors of design practitioners. Design researchers seek to explain designers' behaviors through the causal importance of the structures and processes of cognition, such as prototyping and its psychological outcomes, rather than through their tools and methods *per se* (Gerber & Carroll, 2012). Hence, design cognition research focuses on identifying productive mental representations, structures, and processes for various design situations (Goel & Pirolli, 1992).

Furthermore, a critical limitation of lean start-up and business model canvas and related approaches is their reliance on a structured, step-by-step process (Liedtka & Ogilvie, 2011), which may restrict their usefulness in dynamic business environments. Linearity may be an artifact of pedagogical and communication needs, but we have found, and instructors have noted, that proceeding in a fixed linear sequence can help students see where they are in the process and, more importantly, what knowledge they are gaining with a discrete stage. Yet design scholarship reveals that design as a fixed process does not work, as it may lead to design fixation, "a blind, and sometimes counterproductive adherence to a limited set of ideas in the design process" (Jansson & Smith, 1991, p.4).

Thus, design scholars suggest that problems and solutions must co-evolve to generate the most novel yet feasible solutions (Maher, 2000; Wiltschnig, Christensen, & Ball, 2013). When problem formulation can be modified, there is no clear linear sequence of problem definition, enumeration of solutions, and selection of a solution. Rather, the solution emerges from one problem frame that can be modified as a result of an emergent solution, thereby yielding different solutions (Dorst & Cross, 2001). Similarly, an understanding of the customer problem to be solved can change over time by iterating the proposed solution and its validation, whether through mental simulation (explained later) or physical prototypes.

Hence, it is critical to master a set of cognitive acts that can be flexibly applied in various situations, rather than focus on tools and techniques that risk becoming routinized (such as Porter's Five Forces). Some educators might initially find it helpful to follow the design stages/cognitive acts in a phased manner. Notably, any process or design tool has a set of underlying cognitive acts that can be opaque to practitioners—sometimes deliberately so.

3. THE THINKING IN DESIGN THINKING

This section establishes the cognitive language of design thinking that we apply to entrepreneurship education in the next sections. Design cognition research (Visser, 2006, 2009), as well as option generation research (Garbuio, Lovallo, Porac, & Dong, 2015), have identified four fundamental cognitive acts: framing, analogical reasoning, abductive reasoning, and mental simulation. We briefly introduce these four cognitive acts; the references in Table 2 offer more in-depth theoretical and empirical investigations of them.

A creative solution is based on the novel standpoint from which a problematic situation can be tackled, an act referred to as *framing* (Dorst, 2011). The cognitive act of framing (or reframing a "stale" problem) is widely regarded as a key creative aspect of the design process (Cross, 2006; Lawson, 1997). In entrepreneurship and design, every problem has a problem frame and a solution frame, which are defined through *problem framing* and *solution framing*.

Analogical reasoning is the cognitive act of transferring the properties of a source domain to a target domain based on an abstract conceptualization (mental representation) of structured similarity between the two domains (Holyoak & Thagard, 1995). Analogical reasoning is a part of human cognition (Hofstadter & Sander, 2013), as it can occur spontaneously (Goldschmidt, 1999; Hofstadter, 2001).

Unlike deductive and inductive reasoning, which seek to produce logically true conclusions, *abductive reasoning* is a form of logical reasoning that introduces a hypothesis aimed at explaining observations or data (Peirce, 1931, 1998). The hypothesis may or may not be logically or empirically true. In classical logical reasoning, abductive reasoning proposes the most plausible and parsimonious explanation for observations. Dorst (2011) describes two types of abduction in design: explanatory abduction and innovative abduction. Explanatory abductions introduce hypotheses to explain surprising observations While innovative abductions introduce hypotheses about a new product, service, or system and its working principle that influence the production of the only known observation: the intended value.

Mental simulation involves reassessing past events and imagining future environments before making decisions and taking action (Sanna, 2000). According to Gaglio (2004), mental simulation is a key cognitive act of entrepreneurs as it allows emotions to be re-experienced and helps individuals anticipate physical and social environments by envisioning strategies and tactics to make accurate estimates and enable goal achievement.

Insert Table 2 about here
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4. APPLYING DESIGN COGNITION TO OPPORTUNITY CREATION

In this section, we elaborate on a fundamental theme in entrepreneurial education (Kickul, Janssen-Selvadurai, & Griffiths, 2012) for which the integration of design cognition provides the greatest value: opportunity discovery.[3] We discuss key cognitive acts from design cognition and integrate them into opportunity creation (see Figure 1). Notably, we focus on the thinking aspect of design thinking rather than on tools, techniques, and processes, as the

[3] There is no doubt that business model design, scalability, and financial resources are fundamental to the success of startup companies. However, opportunity creation appears to be the most urgent area for cognition, both theoretically and from an educational point of view.

latter have been extensively discussed in design thinking toolkits (see, e.g., Fraser, 2012; Liedtka & Ogilvie, 2011).

Insert Figure 1 about here

The emergence of opportunities, whether recognized or created, is one of the most discussed topics in entrepreneurial research (Ardichvili, Cardozo, & Ray, 2003; Kirzner, 1973; Schumpeter, 1934; Short, Ketchen, Shook, & Ireland, 2010). A wealth of research identifies preconditions of opportunity recognition, including prior knowledge and external conditions (Shane, 2000; Shepherd & DeTienne, 2005), the thought processes that transform knowledge and observations of the environment into opportunities (Cornelissen & Clarke, 2010; Ucbasaran, Westhead, & Wright, 2009) and the impetus to act on them (Dimov, 2007). Importantly, opportunity creation comprises a large component of entrepreneurship courses and a very specific aspect of entrepreneurial education. Whereas marketing, operations, and strategy are assumed to be prerequisite knowledge for entrepreneurship courses, opportunity creation and the creation of new business models for resource-constrained startups are peculiar aspects of entrepreneurial education (Kickul et al., 2012). While entrepreneurship education research identifies various approaches to search for problems to solve, opportunity creation has often been described as a creative process (Lumpkin, Hills, & Shrader, 2004).

Overcoming the comfort of familiar situations is the key hurdle facing opportunity creation (Berns, 2008). Alvarez and Barney (2010) highlight that prior industry or market experience may actually hinder learning (Sine, Haveman, & Tolbert, 2005; Weick, 1979). While "natural" entrepreneurs and innovators alike constantly question the existing order (Dyer et al., 2008), students often have difficulty looking at the world with fresh eyes to discover unmet needs. Entrepreneurial alertness, information asymmetry, prior knowledge, social networks, personality traits, and type of opportunity all influence the process of opportunity creation (Ardichvili et al., 2003).

Studies in entrepreneurial cognition have highlighted that opportunity emerges from pattern recognition (Baron, 2006; Baron & Ensley, 2006), similarity judgments (Grégoire, Barr, & Shepherd, 2010), and associational thinking (Dyer et al., 2008). Gielnik and coauthors (2012; 2014) investigate the role of divergent thinking, or the general ability to identify multiple original ideas (Guilford, 1950), in opportunity recognition. They postulate that divergent thinking is the end product of more specific cognitive acts, such as conceptual combination, analogical reasoning, and abstraction (Mumford, 2003; Ward, 2007; Welling, 2007). However, from a pedagogical (and experimental) perspective, there is reason to examine these processes separately, as we have done. During opportunity identification, we help students use all four cognitive acts to define and elaborate on ambiguous problems and identify new opportunities (see Figure 2 for examples of usage).

Insert Figure 2 about here

4.1.1. Framing in opportunity creation

Framing aims to establish alternative ways of interpreting situations in accordance with different perspectives on various dimensions. These may be achieved by observing situations involving user behavior, user- or designer-generated problem statements, and even solution concepts and their underlying principles (used to induce backwards the "problems solved"). Specifying when and where framing occurs allows the designer to name and clarify the bounds of problem and solution spaces and provides a systematic way of expanding those spaces.

The most common act of framing is to help students see different types of users and stakeholders as individuals rather than as "average users." For example, when working on a credit card project, it is important to interview not only card users and their families, but also call-center staff, employees in shops where the cards will be used, and even those who cannot afford to use credit cards. In general, the range of problem frames encountered will depend on the sample of users and the manner of data collection.

An in-class reframing exercise that we find effective is inspired by the reframing approach of the Austin Center for Design. In this exercise, Center instructors use a toothbrush as the object of design and ask students to consider three new scenarios. First, they ask them to reframe the toothbrush as it would be used in an atypical environment (e.g., in the kitchen, in an airplane, at a conference). Second, they ask the students to reframe the toothbrush from a different perspective (e.g., for use by a dentist, a hotel housekeeper, a blind date). Third, they ask the students to reframe the toothbrush as a different type of object; what if it were a plant, a spray, or a service? The new frames help students observe unmet customer values, which become novel problems to address.

There are several ways we can induce framing and reframing. ***Abstraction*** is a means of stepping back and reconsidering problems more generally or through opposites. Based on design creativity, abstraction involves prompting students with abstract variations of statements of their current design problem or solution formulation to help them think creatively about problem or solution (Chiu & Shu, 2008; de Vries, Jessurun, Segers, & Achten, 2005; Linsey, Markman, & Wood, 2012). Abstract variations use words that subsume a concept, such as is-a (e.g., a dog is a pet) and has-a (e.g., a dog has a companion) relationships. For example, we prompt students who imagine a start-up aiming to challenge the insurance industry to think in terms of pricing risks rather than selling insurance policies. We could reframe the opportunity in terms of a more abstract concept, pricing intangible value, because risk is an intangible value.

In the classroom, we have implemented abstraction in the spirit, if not the form, of experiential learning (Amador, Miles, & Peters, 2006; Duch, Groh, & Allen, 2001; Kolb, 1984). Rather than teaching this framing technique to students directly, we let them explore different ways of looking at a situation by organizing a simulated experimental session in class. After organizing the class into two groups, we ask one group to redesign an object (e.g., the classroom) and the other to redesign a concept (e.g., how we educate people). When we move toward the solution stage, the second group systematically provides many and more interesting solutions because it had a larger problem space. Some of these solutions might not be feasible, but this is not important during the opportunity-identification stage.

Directing students to ***think in opposites and extremes*** can help them frame situations in novel ways to reveal new dimensions and perspectives. Thinking in opposites is a common method of creative thinking (Rothenberg, 1973). For example, when students are looking for opportunities for a new insurance startup, instead of having them focus on innovative ways to "price risk" (the fundamental activity of an insurance company), we ask them to "price love." This challenge sparks ideas they would not have discovered if the focus had been on the insurance business itself. They may then apply analogical reasoning, as they wonder how they can adopt principles from companies that price love (e.g., De Beers) to the situation at hand.

4.1.2. Abduction in opportunity creation

Abductive reasoning is a cognitive act in which we invent a hypothesis to explain observations that are often surprising. Importantly, these hypotheses may or may not be logically or scientifically true. If the hypotheses were already known to be true, there would not be much scope for entrepreneurial action since revenue generation models would be well established. Getting students to recognize that they are involved in abductive reasoning is important, as it helps alleviate the bias of prior knowledge or known reasons.

The two types of abductive reasoning are useful in two different circumstances: when we are inferring reasons for an observation (e.g., a user behavior) and when we infer an idea that a user will respond to in certain ways. ***Explanatory abduction,*** is a form of reasoning in which individuals hypothesize novel explanations to empirical observations. The aim is to avoid pattern-recognition bias by explaining observations through recourse to alternative relationships between causes and effects. This is the typical instance in which we ask students to explicitly search for surprising facts and observations that show some value to users and then find a cause-effect relationship that explains them.

The second, ***innovative abduction,*** is a form of reasoning in which we hypothesize about what to create (i.e., product, service, or system) and its working principle to arrive at an aspired value (the only "known") (Dorst, 2011). The hypothesis explains the causal reasons for the existence of the value; that is, if the hypothesis turns out to be empirically true, then the value exists. In this case, the challenge is not only to understand what needs to be true to support the observation or what new value to create for the user, but also to come up with a new rule that makes the new value come alive, such as the need to create a new business model (for more details, see Dong, Garbuio, and Lovallo (2016a, 2016b)).

In facilitating prospective and actual entrepreneurs in our classes to construct abductive hypotheses, we have observed two characteristics. First, the process helps prospective entrepreneurs better qualify and quantify the market need and value of their proposed offering, as it grounds their assumptions in actual behaviors and observations rather than in secondary research on markets and segments. Second, we find that prospective entrepreneurs generate opportunities to satisfy needs that go beyond the offering they originally had in mind. For instance, during the study of a user experience at the movies, students originally hypothesized that the user who was going to the movies regularly was looking for "a convenient offer". A more robust ethnography (e.g., observations of filmgoers), open-ended interviewing, and a lecturer's recollection of seeing Japanese businessmen dressed in suits watching movies in the middle of the day identified the surprising observation that many filmgoers did not search for a movie to watch – they simply went into the theater.

The students hypothesized instead that moviegoers were looking for "an escape-life opportunity.

Overall, to help students in their journey, we stress the importance of observations that students find surprising (given their knowledge), workarounds that users employ, and contradictions (e.g., between what the user says and her behavior). These points are often sufficient to help students create hypotheses to explain their observations of (possibly true reasons for) customers' behaviors and, in so doing, to help them break free of existing preconceptions, such as "believed sources of problems."

4.1.3. Analogical reasoning in opportunity creation

New opportunities can emerge from making novel associations between existing things (Bar, 2009) and learning from others' success and mistakes. Analogical reasoning hence assists in increasing opportunity creation and productivity. Analogies have figured prominently as inspirations for architectural design, wherein a building is designed to "look like" a natural object, but also to exert a framework over subsequent sequences of problem formulation, interpretation, and solution assessment (Rowe, 1982). In design cognition, analogies are used in problem formulation (Visser, 1996), problem solving (i.e., ideation of solutions and "inspiration" (Goel, 1997; Holyoak & Thagard, 1996; Rowe, 1982)), and uncertainty resolution to explain whether proposed solutions could work (Ball & Christensen, 2009). Scholars have identified two types of analogies: within-domain (close field) and between-domain (far field) analogies (Vosniadou & Ortony, 1989). Between-domain analogies typically are used in problem formulation (in our case, primarily in opportunity creation); within-domain analogies are primarily used in uncertainty resolution; and solution-oriented analogies are a mixture of within- and between-domain analogies (Christensen & Schunn, 2009).

At the most basic level, working with analogies forces students to explore the source of the analogy (the exemplar) and its structural characteristics, and to transfer these solution principles to the case at hand (Blanchette & Dunbar, 2000). Instead of letting students use the exemplar at a very basic level (e.g., we should be the Uber of our industry), we ask them to identify key characteristics of the exemplar (e.g., the matching mechanisms, the entry strategy) and examine the extent to which these characteristics can be transferred to the target domain.

An intriguing application of analogical reasoning lies in thinking about a new product, service or business model using the analogs and antilogs technique. As Mullins and Komisar (2009) discuss, business ideas do not have to be revolutionary; rather, entrepreneurs can develop them by looking at analogs—what has worked in the past—and imitating or building on these exemplars. Ideas can also be developed by looking at antilogs—businesses that have been unsuccessful—and avoiding past mistakes (Mullins & Komisar, 2009).

We use the example of Apple's iPod to explain analogs and antilogs. In a reverse-engineering exercise, we could say that the Sony Walkman is the analog that inspired Apple. Because the Walkman proved that millions of people were willing to pay for a device that allow them to listen to music on the go, Apple did not need to create or validate this hypothesis.[4] Apple also could have developed valuable insights by looking at antilogs, such as Napster, to develop a legitimate platform for downloading music: the iTunes store. The popularity of Napster as a peer-to-peer music-sharing site signified a growing trend toward downloading music. After piracy and illegal downloading led to Napster's ultimate failure, Apple created an online store where people could download and save music after paying a small fee to avoid such legal issues.

[4] Note how this hypothesis was confirmed. Prior to this confirmation, it was an abductive hypothesis. In this case, we used analogical reasoning to confirm a hypothesis. In fact, the invention of the Walkman itself also depended on the abductive hypothesis and analogy that people would enjoy personalized music on the go, just as they enjoy other personalized experiences on the go, such as reading newspapers or talking.

4.1.4. Mental simulation in opportunity creation

Mental simulation is proposed as a key cognitive act for opportunity creation (Gaglio, 2004), especially once a proposal for a new product, service or business model has been devised. Mental simulation helps the transition from a newly identified opportunity to a better one, allowing for predictions of the outcomes of its possible implementation, even in the absence of data or previous experience. Unlike traditional means of prototyping, which only focus on a single user's perspective, mental simulation illustrates the broad class of simulative experiences necessary to operate a competitive business.

Once students have identified a new opportunity, we ask them to mental simulate in two areas. First, we focus on how to make the opportunity work in the marketplace from a business model perspective. Next, we ask them to simulate the scaling of the business, such as expanding into new occasions of consumption and new geographies. Third, we ask students to mentally simulate competitors' reactions. We ask them to go beyond identifying which competitors and competing technologies are capable of thwarting the new venture to stress-test the opportunity. This last step can be supported by traditional business model and strategy frameworks (Hambrick & Frederickson, 2001; Porter, 1980). More specifically, we encourage students to consider the following questions: Are these customer needs scalable to other customer segments? How will competitors react? How will we defend our position? Who are we displacing in the value chain? Do we have the capabilities needed to produce the new offering? Which capabilities are we missing? Do we need partners? Will we create value for them? In sum, mental simulation help them identify deficiencies and contradictions within the structure of the solution and fundamentally improve it (Dörner, 1999).

5. A THOUGHT EXPERIMENT

In this section, we illustrate how we use the cognitive acts to help students identify new opportunities, whether products, services, or business models. Figure 3 summarizes our eight-step approach to better understanding opportunity creation, which we describe in detail below. Notably, educators do not have to follow this process step by step, just as their students won't as they identify extraordinary opportunities. However, this process should help them get a flavor for the cognitive acts that are in play.

Insert Figure 2 about here

At the very start, we ask the students to identify the problem they are trying to solve—e.g., from a user perspective—and any solution that is already available or that they have in mind (typically, a very rough idea of what the new product or service will look like). For the first step, we question students to help them reframe the problem from a different user perspective or by describe the problem more abstractly. For example, we might reframe the problem of reducing street violence by reframing it as the problem of how to help young people have fun in their free time. This allows us to view the problem broadly and solve different kinds of problems. An example from a different industry or even a different biological system (analogical reasoning) can also be useful. We might ask, how would nature solve this problem? Bio-mimicry and biological analogies are fairly common sources of inspiration for new frames in architecture and design (Benyus, 1997; Mazzoleni, 2013).

Second, we ask students to create (innovative abductive) hypothesis for a new offering. When students are stuck, we prompt them to think about different user needs, different types of users, and completely new services and occasions of consumption. The innovative abduction will help generate a new problem frame and solution frame.

Third, we ask them to state the new frames, which will be the focus of the rest of the thought process. Generally, the new frames tend to be broader than the initial ones, allowing for greater opportunities for innovation as they target larger, new, or emerging markets.

Fourth, we ask students to consider how to make an opportunity work in practice. At this stage, the solution concept might still be very hypothetical (Is it technically feasible? Financially viable?). It is often useful to find an analogy and transfer the principles from one existing, proven solution to the case at hand. Typical prompts might include: "What would you do if you were Uber? What would you do if you were eBay?" Such questions help students think about a problem more abstractly (for example, as a platform business or a platform-based marketplace). Design by analogy is a powerful technique, as numerous products and architectural forms have been designed through being based on analogies with nature or forms in other domains. In architecture for instance, one of the most well-known is the Sydney Opera House, whose roofs mimics sails (Dorst, 2015). In business, the common business model of a razor and blades mimics Gillette's original sales proposition.

The fifth step is to create an explanatory (abductive) hypothesis to explain the existence of the new product and a hypothesis that would negate the existence of the new product. Typical questions we use to encourage explanatory abduction include, "Is there a market for this problem if we use this kind of solution? Can it work?"

Sixth, we ask students to state the new opportunity in terms of "value that is delivered to the customers" as well as the business models that emerged from the previous two steps.

Seventh, since the opportunity might still have several uncertainties (e.g., Is there a market? How big is it? How urgent is the need for a solution? What will competitors do?), we use mental simulation to prune off ideas that might be interesting but not currently feasible, such as a lack of capabilities or available customers. Once these non-ideal solutions have been eliminated, we are left with a solution that the students feel comfortable pushing forward (that is, we have reduced the psychological uncertainty of facing the unknown).

Finally, we can restate the problem and solution frames, and use more traditional tools, such as strategic analysis, marketing planning, financial planning, to further develop and validate the solution.

6. RECOMMENDATIONS FOR EDUCATORS

Educators of design thinking have to transition to teaching in a team-, project-, and studio-based learning environment. This section provides recommendations on introducing design cognition within a problem- and team-based pedagogy, which is the common approach to entrepreneurship education. We then discuss the environment, based on studio learning; the role of lecturers as coaches; external support from designers and the design community; and the importance of students' critical reflection as a key learning tool.

6.1. Design and Project-based Education

Design education is fundamentally different from managerial education, as it is more about coaching students in the discovery of problem and solution spaces than spoon-feeding them information. Students who are accustomed to more common, traditional didactic teaching methods tend to resist this new approach due to its uncertainty, messiness, and highly qualitative, real-world aspects.

It is useful to keep in mind certain practices common to all project-based learning approaches. First, if a client buys into the design process and is willing to accept, a modifiable brief can be a useful starting point to transform a traditional course into a design-based one. The problem statement is often bounded by the client's needs, which can address some of the variables that students would otherwise have to explore themselves (e.g., Which real problem should we solve? What situation should we study?). This "realness" comes from the client providing objective and real feedback on the usefulness and appropriateness within the actual domain for the output of each step. Of course, this is not always possible or even advisable when the goal of the course is a full-immersion entrepreneurial journey from opportunity identification to business model design. However, when the goal is to nurture entrepreneurial mindsets in a relatively safe environment, the use of a client brief has proven to be helpful.

Second, continuous assessment is necessary in project-based learning. Having milestones related to specific deliverables and "stages" of the process will help keep projects aligned and moving forward. Under the true design approach, each team may slip back or move ahead in stages, depending on its effort and returns on effort. However, teams should illustrate learning points from their project on a regular basis.

Third, as project-based learning is effectively team-based learning, traditional measures used to assure effective teamwork are needed (e.g., team composition, leadership, and management processes). Much of the learning also comes from an appreciation of how teams generate different or unique solutions to the same problem. Therefore, it is important that teams share their intermediate and final outputs wherever possible.

Finally, design projects are often most effective when teams are multidisciplinary. Well-known multidisciplinary programs such as Stanford's d.school and Rotman's DesignWorks actively seek to "seed" their teams with students from different disciplines, such as business, engineering, and design (Fixson, 2009; Fixson, Greenberg, & Zacharakis, 2015a; Fraser, 2012; Vogel, Cagan, & Mather, 1997). An engineering or medical student will bring different perspectives on user problems and available technologies, as well as different problem-solving mindsets than those found in business schools.

6.2. The Environment: Studio Learning

To facilitate this work, students need space to develop their ideas, both individually and as a group. Design studios commonly used in fields such as architecture, industrial design, and art have been adopted for design thinking spaces (Barry & Meisiek, 2015; Doorley & Witthoft, 2011). Many design studios have artifacts as their output require physical space. Similarly, design-driven entrepreneurship education needs a space where we can display and continually see research (as suggested by cognitive load theory, see Lee and Anderson (2013)) to remind students of their journey toward a final goal. The team is usually composed in a very close setting that encourages collaborative work. In the studio-learning environment, we bring the entire class together to share moments that facilitate additional cross-team learning and reflection while instructors serve as mentors, advisors, consultants, and critics (Fixson, 2009).

Spaces should be reconfigurable and readily available (Doorley & Witthoft, 2011), and they should feel comfortable and relaxed. Teams working for long periods may need space to store artifacts, whiteboards, and prototypes. Physical space should be designed to support the skills and mindsets required by innovating activities (Fixson, Seidel, & Bailey, 2015b) and the practice of the cognitive acts. Well-known design spaces, such as those at Stanford's d.school and Babson College's Design Zone, have a sparse, industrial look and reconfigurable furniture that encourages participants to explore and rearrange the space as their projects and ideas evolve (Barry & Meisiek, 2015; Doorley & Witthoft, 2011; Fixson et al., 2015b). Rapid prototyping tools are increasingly a part of the setting, especially entrepreneurship spaces associated with engineering schools.

6.3. The Instructors: Lecturers as Coaches

As a mentor and advisor, the lecturer's role is to help students examine a problem or solution from different angles and see each perspective's strengths and weaknesses (Gómez Puente et al., 2013a). Students often have a hard time recognizing the purpose of "following process," which is not to tie them down but to strengthen and organize their thinking. An examination of the conversation in design reviews and entrepreneurship pitches found substantial differences in the thinking processes of groups taught with the traditional didactic approach and those taught with a design-driven approach (Dong, Garbuio, & Lovallo, 2016c). In the former groups, questions were aimed at killing ideas, somewhat prematurely in the design process; in the latter, questions were asked to stimulate new hypotheses and opportunities.

In our classes, we have found it is useful to clarify our position at the beginning of the semester. We highlight how we assist students in generating questions that lead them to the answers (describing it as a sort of Socratic method for philosophy and law students), whether they need to bring it to the fore or search for it. We also explain that, due to the open-ended nature of the problems we are dealing with, the answers are sometimes unknown.

6.4. External support: Leveraging designers in class

While designers may be new to business practice, instructors can benefit from encouraging them to creatively cross-fertilize ideas, practices, and knowledge. To effectively implement the design-driven approach, we recommend that instructors look for assistance from designers who understand design cognition rather than design processes and who are able to mentor students in the co-evolution of problem and solution frames or to co-mentor with business-trained instructors in framing exercises. Students should learn the cognitive acts, which are more generalizable and useful for them in the long run than specific tools and techniques.

For instructors seeking to adopt a design-driven approach to entrepreneurship education, we recommend a gradual transformation that begins with shadowing someone else, then developing one's own materials. In the end, design is still a "practiced" art more than a science. We have found it useful to attend classes taught by designers or design-trained faculty to absorb teaching methods and to understand the subtleties of various processes and tools. Designers from traditional design professions can shed light on their creative processes and ways of thinking. But unless they have been working in a real-world domain related to what is being designed, they may not be as helpful at solving actual service-design problems. We also find that inviting designers to class to discuss their problems (or, if serving as clients, to discuss the problems they are posing to the class) and problem-solving approaches as "case studies" can help introduce students to the "whys" of design thinking and its methods (i.e., why employ a certain technique at a certain point in time).

Importantly, the teaching team should include not only designers but also staff from multiple fields. Indeed, the discovery of opportunities is not a single-person or single-insight attribution (Dimov, 2007), but rather the result of a process in which a set of unitary, distinct events lead to the emergence of a pattern (Oliver & Roos, 2005). Hence, we encourage a multidisciplinary approach in which design, engineering, and law students attend entrepreneurship classes with business students.

6.5. The Students: Critical Reflection

Fundamental to both design (Dong, Kleinsmann, & Deken, 2013; Valkenburg & Dorst, 1998) and management (Schön, 1983), reflection helps students extrapolate learning from a situation and improve their cognitive skills. At the end of each activity (e.g., observation or interview), we ask the students to reflect in a systematic way using a learning template. We first ask them to acknowledge their previous knowledge and experiences on a similar task, then about the surprises that emerged from this new application, and ultimately how the experience is changing the way they will approach similar situations.

7. CONCLUDING THOUGHTS

7.1. Implications for Entrepreneurship Scholarship

Appling design cognition to entrepreneurship education raises several potentially fruitful implications for the teaching of entrepreneurship. First, entrepreneurs' awareness of cognitive acts enables them to apply these acts with the most appropriate tools or even to design their own tools. Importantly, whereas the processes, techniques, and tools are sometimes not transferable to other domains, cognition is. For example, applying an overly rigid user experience perspective when designing a market entry strategy for a start-up creates the risk of developing a myopic strategy that only satisfies customers who have been observed or interviewed as part of the opportunity discovery phase. By contrast, through the continuous act of observing and framing, entrepreneurs can recognize evolving needs and thus adapt their offerings and strategies.

Another appealing aspect of the cognitive view on design thinking is that the cognitive acts demystify notions of creative insight or "genius" in both design and entrepreneurship. Instead, fluency in a relatively ordinary set of cognitive acts can support the framing of a novel problem space through distant analogical references and the formation of possible corresponding solutions. This fluency can also increase confidence (and decrease psychological uncertainty) that the correct problem and a set of plausible solutions have been identified through within-domain analogies and mental simulation. As such, design thinking does not arise solely from the application of a defined set of activities but rather through the application of particular ways of thinking. As we have attempted to convey, it is not possible to provide a set of tools for design, from journey mapping to prototyping, without teaching a set of cognitive acts to accompany them (Kumar, 2012).[5] The cognitive acts are at least as important as mechanical design skills, such as diagramming, sketching, and prototyping.

7.2. Future Research

Design-driven entrepreneurial education opens further research opportunities. First, much of our discussion has discussed how individual cognition is exercised in class settings and as a result of in-class activities. However, several studies find that opportunity discovery is not a single-person and single-insight attribution (Dimov, 2007), but rather the result of a

[5] Typical tools used in design thinking include, for gathering data on customers' experiences: customer journey mapping, empathy maps, and employment of the "five whys" (root cause analysis); for brainstorming, tools include classical group brainstorming techniques, mnemonics for helping transform knowledge such as the SCAMPER technique; and finally, tools for prototyping include sketching, rough prototyping, storyboarding, and various service prototypes. Cognitive tools are ones that naturally rely more on the cognitive faculties, such as keen observational skills for data gathering, analogical mappings for brainstorming, and mental simulation for prototyping.

process in which a set of unitary, distinct events lead to the emergence of a pattern (Oliver & Roos, 2005). This is particularly relevant in technology entrepreneurship, which has been found to be more effective when it is built on the efforts of many (Garud & Karnøe, 2003). Van Burg and Romme (2014) suggest social aspects of entrepreneurial cognition that can be studied in conjunction with the design cognition approach. We encourage further studies that examine the application of cognitive acts to team-based learning in the context of entrepreneurial opportunity creation.

Further, while we treat a problem and its solutions as separate elements in a design process, we recognize that they coexist and, often, when treated as separate activities (e.g., problem identification through fieldwork), coevolve over time (Dorst & Cross, 2001): new solutions may suggest a new presentation of the problem, and new problems may require new solutions. Qualitative and quantitative studies that investigate how problems and solutions co-evolve over time in entrepreneurial education could suggest more effective teaching methods.

The approach presented in this paper is corroborated by many years of global design research and design disciplines, but is based only on our experience teaching entrepreneurship over the past seven years. Our hope is that we have begun to spread a new way of looking at design that can be effectively applied to entrepreneurship education. The lean start-up and business model canvas approaches have been widely adapted but largely untested as educational tools. In fact, although appealing from an educational perspective, these approaches might not be appropriate for complex engineered products with long lead times and high capital requirements. We hope that educators now have a greater choice of tools to experiment with in the classroom.

TABLE 1: Summary of key entrepreneurship education approaches

Approach and main references	Approach to teaching and learning	Key Benefits	Key Criticisms
Business plan development (Barringer, 2009; Honig, 2004; Kaplan & Warren, 2009; Kuratko, 2003) The systematic analysis and business plan are used to collect information that helps entrepreneurs make decisions in highly complex and uncertain environments.	- Teach and monitor production of business plans internally or via jury - Usually done in groups where individuals split tasks and produce a report	- A positive influence on performance, in terms of growth and profitability (Bracker, Keats, & Pearson, 1988; Schwenk & Shrader, 1993) and firm's survival after 18 months (Delmar & Shane, 2003)	- Controversial debate on the positive impact on performance (Boyd, 1991; Robinson, 1979; Robinson & Pearce, 1984; Robinson, 1984) - Environmental uncertainty and dynamism diminish value of business planning (Honig, 2004) in favor of more agile approaches (e.g., lean startup) - Focus on ideas rather than actions
Contingency planning (Abetti & Phan, 2004; Gruber, 2007; Honig, 2004) Adaptive business planning that takes into account environmental factors. In highly dynamic environments, only specific activities are planned to speed up the starting up process, while, in slow environments, an in-depth planning is preferred.	- Taught as unrelated modules - Similar to approach used to train medical interns who follow an expert and make diagnoses.	- Positive impact on venture performance (Gruber, 2007); value varies with the type of activities, effort devoted to specific activities, and time spent on planning - Lead students to practice divergent thinking, try out new ideas, and receive feedbacks on specific elements at any time (Honig, 2004)	- Limited empirical evidences to support the positive effect on performance - Difficulty in assessment design, as educators have to be content with completed modules (instead of completed business plan) that may not be related to one another - Exhaustive planning is inferior to selective planning in highly dynamic environment where speed is critical.

Approach and main references	Approach to teaching and learning	Key Benefits	Key Criticisms
Effectual entrepreneurship (Dew, Read, Sarasvathy, & Wiltbank, 2009; Sarasvathy, 2001) Entrepreneurs do not start with concrete goals but constantly develop them on the fly through personal strengths and available resources.	- Use cases and guided discussions to help students adopt and practice an entrepreneurial mindset - Focus on differences in framing between expert entrepreneurs who redefine the frame to look for new solutions (effectual) and novices who accept the frame and look for opportunities within it - Analogical reasoning allows students to go beyond data	- Assist in creating opportunities and new solutions to control a future that is inherently unpredictable - Realization that surprises are not always bad (as opposed to the avoidance of surprises in causal reasoning)	- Effectual research is only now transitioning from a nascent to an intermediate state - A need for more empirical studies. Existing findings are inconsistent, relying on a small sample size and relatively open-ended data that requires interpretation (Perry, Chandler, & Markova, 2012)
Process perspective (Aulet, 2013; Baron, 2006; Hjorth & Johannisson, 2007) Entrepreneurial process begins with opportunity recognition and can be learned and entrepreneurs can be trained to better recognize opportunities.	- Focus on a process which unfolds over time, with each stage requiring different knowledge and skills - Opportunity identification is taught through classic strategy tools (e.g., market segmentation, end user profile) and cognitive framework - Focus on training entrepreneurs when to direct their attention and on the process of searching for patterns	- Offer a systematic guide and help avoid a static view that ignores ever-changing challenges - Draw attention to the key activities that must be performed as ideas are converted into businesses - Emphasize the varying effects of each factor over time and over the course of new venture creation	- Only a few models of entrepreneurial process are grounded in empirical investigation(Moroz & Hindle, 2012) - Only a few studies in this approach focus on providing practical implications that address the "how" of entrepreneurship

Approach and main references	Approach to teaching and learning	Key Benefits	Key Criticisms
Opportunity-centered learning (Rae, 2003) Exploration and development of an opportunity through individual and group investigation, understanding, selecting, and acting on an opportunity	- Students to explore the opportunity (through brainstorming, use of post-it notes, and directed creativity); relate the opportunity to personal goals, plan to realize the opportunity, and act to make the opportunity happen - Use of exploratory questions and a short case to illustrate an entrepreneurial learning process	- Ideal approach when learning outcomes are to transfer theory to practice and develop personal and team skills - Allow students from different backgrounds to use the approach within a single session - More engaging than problem-solving approach	- Only appropriate for a small class (20-30 students) with a minimum of three two-hour sessions, as the learning value is significantly reduced in large groups and compressed time scales - Tutors with strong leadership (e.g., multi-group facilitation) are critical for the success of this approach - Students with low self-confidence or underdeveloped self-organization and teamwork skills might be at disadvantage
Lean start-up approach (Blank, 2013; Ries, 2011) Hypothesis-driven approach that focuses on experimenting rather than planning. Directly engaging with customers through a minimum viable product, which is built iteratively and incrementally according to customer feedback	- Often uses graphical representation of business models, such as lean canvas (Maurya, 2012) or business model canvas (Osterwalder & Pigneur, 2010), to develop testable hypotheses - Engage in a dialogue with customers about product development (agile development) instead of forecasting financial return	- May reduce the failure rate, as the new product goes through several iterations of refinement based on customer feedback - Minimal viable product (MPV) allows for fast and cheap launches to test an idea and eliminates wasteful time on features customers don't want	- Only suitable for certain types of products, as MPV might lead students to overlook basic issues (e.g., viability, quality) and discourage them from trying to solve and test comprehensive solutions - Encourage students to think short-term (e.g., superficial new features that lead to a product that is not deep) - Very demanding, in terms of resources that could prematurely burn out a team

Table 2: Summary of the four cognitive acts in design cognition research

	Design cognition	*Further specifications and examples*
Framing	Generative process of drawing associations and dissociations between the situation, assumptions, and precedence to produce a schema for their interpretation, which makes it possible to clarify the detailed requirements of the problem and determine the extent to which the proposed solution can satisfy them. *Key works: Schön (1983); Dorst (2011); Stumpf and McDonnell (2002); Cross (2006); Lawson (1997)*	In solving the problem of crime in a neighborhood, framing the problem from a policing perspective may regard the problem as one of curbing anti-social behavior, whereas framing the problem from a resident's perspective may regard the problem as one of improving social amenities. The content of the frame makes it possible for the designer to identify salient requirements and determine the extent to which the proposed solution can satisfy them. The frame connects surveillance to curbing anti-social behavior, and parks and social clubs to improving social amenities. It is considered by some to be a key strategy in design cognition. See Dorst (2011).
Analogical reasoning	Act of identifying and carrying over knowledge from prior situations to support the current situation. Analogical reasoning can involve within-domain (close field) and between-domain (far field) analogies. Between-domain analogies are normally used in problem formulation; within-domain analogies are primarily used in uncertainty resolution; and solution-oriented analogies are a mixture of within- and between-domain. Research shows that introducing between-domain design cases to prime analogical reasoning results in novel solutions when the goals of the design situation are open. *Key works: Dorst (2011); Holyoak and Thagard (1995); Hofstadter and Sander (2013); Leclercq and Heylighen (2002); Christensen and Schunn (2007); Ball and Christensen (2009); Ahmed and Christensen (2009); Ball et al. (2004)*	Within-domain analogical reasoning is straightforward. Example of between-domain analogies: to identify a new opportunity for a company operating in the healthcare industry (a heavily regulated environment that has numerous dynamic startups), you can study companies that operate with innovative business models in challenging environments. Alternatively, you can investigate how microorganisms have overcome challenges to survive in hostile environments. While healthcare delivery and microorganisms are indeed very different on the surface, the use of analogical reasoning forces you to focus on whether the problems might share some important characteristics.

Abductive reasoning	Act of proposing a hypothesis to explain the data, especially surprising information, to identify "what might be" rather than the current or previous state of affairs. Abductive reasoning can have either explanatory or innovative purposes. *Key work: Dorst (2011); Kolko (2010); Peirce (1931, 1998); Roozenburg (1993);*	*Explanatory abduction* creates hypotheses to explain some (surprising) news while working with a limited set of data to come up with the *most plausible and parsimonious explanation for given observations* – for instance, this happens when an entrepreneur is trying to interpret the reaction of an incumbent in the industry. *Innovative abduction* is employed by inventing a new product or business model. An entrepreneur must propose both a new idea (e.g., a new value to create for customers) and the means for executing the new idea (e.g., a business model), with the premises (links between the components) that are surmised to allow it to work.
Mental simulation (mental time travel in cognitive science)	The act of mentally trying out the operation of an opportunity or business model to predict its outcomes in the absence of data or previous experiences. *Key works: Markman, Klein, and Suhr (2012); Ball and Christensen (2009); Ball, Onarheim, and Christensen (2010); Heylighen and Nijs (in-press); Bilda and Gero (2007)*	Mental simulation is used when there is less than complete knowledge about an anticipated future into which a new design will be introduced, often entailing a large number of possibilities. The mental representation of a design solution entails the assembly, combination, and recombination of individual elements; mental simulation is brought in to consider the effects caused by a change in any elements. Mental simulation appears to reduce the psychological uncertainties that designers face during the course of their work, such as the concern that they do not fully understand a somewhat complex design problem, the efficacy of proposed design solutions, or how end-users will interact with the product. For example, using well-established frameworks, such as the business model canvas, PESTEL, or the strategy diamond, we ask students to mentally simulate all possible scenarios and in particular how external shocks (e.g., changes in regulation and technology) and competitors' actions will affect the new venture.

FIGURE 1: How design cognition supports entrepreneurship education

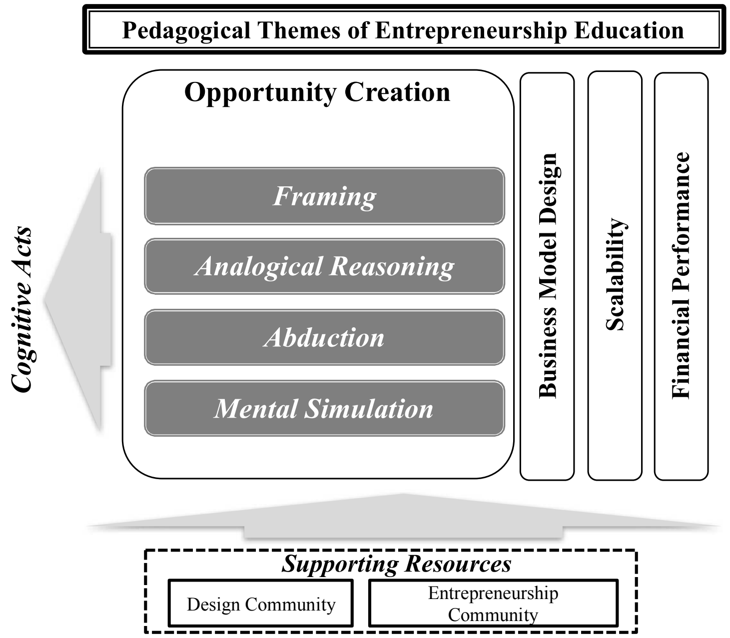
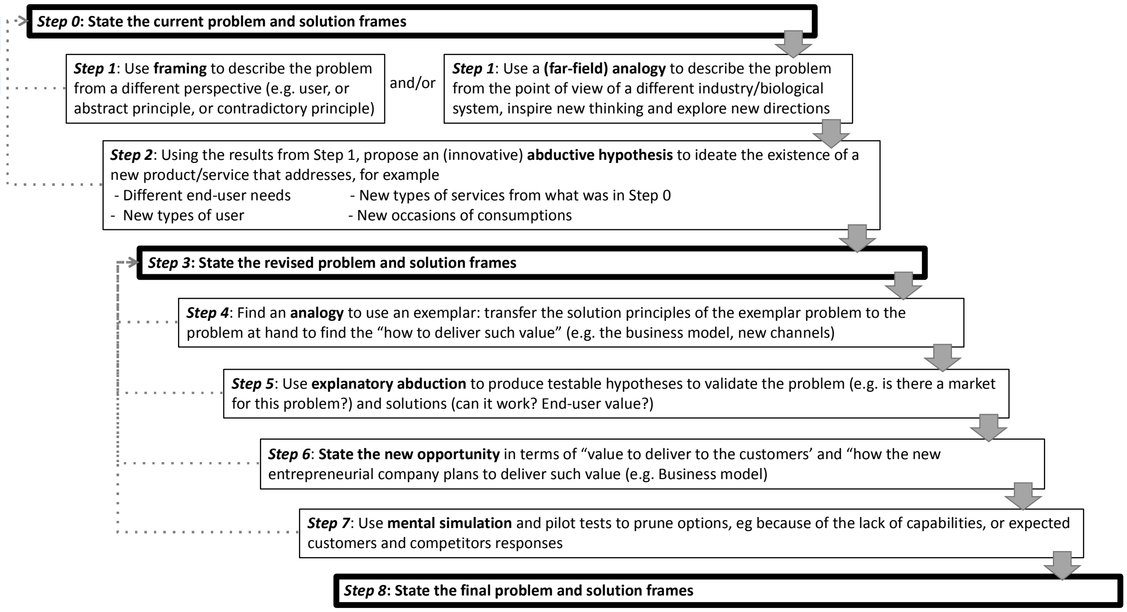


FIGURE 2: Examples of usage of cognitive acts in entrepreneurship education

Cognitive act	Example of application
Framing	Abstract Variation to observe the opportunity from different points of view
	Opposites to identify constrains and boundaries to generate solution concepts
Analogical Reasoning	Between domains comparisons to transfer solutions from one domain to another
	Analogs & Antilogs to generate solution concepts starting from business models that worked and did not work in past situations
Abduction	Hypothesizing novel solution principles to existing problems
	Hypothesizing novel explanations to emerging business models
Mental Simulation	Validating solution ideas in different contexts of use
	Validating new products and services

FIGURE 3: AN EIGHT STEP APPROACH TO BETTER OPPORTUNITY GENERATION AND BUSINESS MODEL IDEATION



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