Chapter 3

Toward a Matrix of Situated Design Cognition

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Abstract

Design is commonly associated with cognitive frameworks for teaching and analysis. However, the nature of design extends beyond cognition to social and dynamic contexts. Situated cognition, which posits that knowing cannot be separated from doing or social contexts, may be an appropriate perspective with which to analyze design teaching and learning. This monograph summarizes dimensions of design from the work of Crismond and Adams (2012) and distills five dimensions of situated cognition from Driscoll (2005). These two concepts are compared, with similarities identified and implications for design teaching and learning described. A matrix of situated design cognition is presented for further investigation and theory building.

Keywords: design, design cognition, situated cognition, design pedagogical content knowledge (PCK)

Toward a Matrix of Situated Design Cognition

Design is the process of forming plans and developing products to solve a problem or address an opportunity to meet human needs or desires. It is a distinct type of problem solving (Jonassen, 2000) that appears in many fields of study. For example, "instructional," "interior," "engineering," and "web" can all be appended with the word "design" and produce a coherent meaning. Though design appears in many disciplines, it can be considered a distinct domain with ways of acting and knowing (Cross, 1982). The study of design in this way involves a "unifying core" that spans these disciplines and subsequently informs practice in each (Goel & Pirolli, 1992, p. 397). Developing an understanding of how designers think and behave in the face of uncertainty is important for improving practice—both for designing and teaching design.

These patterns of thinking have been subject to much investigation, being called *design cognition*. As Dym, Agogino, Eris, Frey, and Leifer (2005) state, the process of problem formulation and solution generation is a complex cognitive process. Yet, the breadth of design activity includes aspects unaddressed by many of the available cognitive frameworks. And if we hope to effectively teach design, we must teach its full nature and how it is enacted by designers (International Technology Education Association, 2007; Todd Kelley & Rayala, 2011).

Therefore, we have synthesized dimensions of design and situated cognition to offer a reoriented perspective on design cognition that accounts for the highly-situated nature of design practice. The resulting perspective is presented as a matrix of situated design cognition. In the subsequent sections, the dimensions of design cognition and situated cognition are described, methods for comparing situated cognition theories and design activity are presented, and the matrix of situated design cognition is discussed. This emerging connection of design and situated cognition holds implications for design teaching and research.

A Focus on Design Cognition

Design has been characterized as a cognitive task because it generally involves the external representation of mental structures: forming a mental picture of a situation and bringing it about (Goel & Pirolli, 1992). More specifically design involves forming an understanding of problems, potential solutions, and making judgments and decisions about what ideas to pursue—all mental activities (Daugherty, Mentzer, & Kelley, 2011). Todd Kelley and Rayala (2011) describe several motives for studying and understanding design cognition: as a means for establishing interventions to improve design teaching and evaluating current design curricular efforts. Both of these aims, and the intent of design cognition research generally, are to establish better methods to prepare future designers (Adams, Turns, & Atman, 2003). Moreover, Wilson-Lopez, Smith, and Householder (2013) claim it is essential to examine design cognition at all levels—from adolescents to advanced practitioners—in order to identify strategies for fully supporting adolescents as they develop the habits of mind practiced by professional designers, such as engineers.

A variety of design cognition taxonomies have been established and employed in design cognition research. Taxonomies have been derived from the actions of design practitioners, design process models presented in design curriculum, analyses of engineering textbooks, or cognitive science frameworks. Grubbs and Strimel (2016) categorized these taxonomies based on their foundations as either a general design process, practitioner design process, or cognitive science taxonomy of design. Examination of design cognition studies conducted between 1996 and 2016 revealed eight different taxonomies used to define the cognitive tasks associated with design work (Grubbs, Strimel, & Kim, 2018; Strimel & Grubbs, 2017). Each of these cognitive activity taxonomies was found to have a distinct foundation and intent. The eight identified design cognition taxonomies and their originating source are provided in Table 1.

Since cognition is, by definition, unobservable, these lists of activities represent various attempts to uncover what designers are doing while designing. This representation of cognitive tasks during design is important for design educators to understand so that instruction can effectively instill expertise; similarly, the underlying modes of design thinking are important for learners to understand so that observations can be instructional. Investigations of design cognition are numerous (Cross, 2001) and span grade levels from elementary to undergraduate (Lammi & Gero, 2011). Among the results are insights regarding how long designers with varying levels of expertise spend on design, how frequently they switch tasks and iterate, how often they seek out information about the problem, and how they visualize their work (Atman et al., 2007; Cardella, Atman, & Adams, 2006; Mentzer, 2014).

Because each of these design cognition findings may be meaningful for design education, Crismond and Adams (2012) put many of these findings together in an attempt to inform design teaching. Their scholarship of integration identified core dimensions of design, and produced a matrix of behavioral patterns and how they intersect with each dimension. Each specific behavioral pattern included novice to informed designer comparisons and instructional recommendations. In contrast to other problem-solving investigations which made novice–expert comparisons (e.g., Chi, Feltovich, & Glaser, 1981), informed design was chosen as a more meaningful school-based outcome than expert design—informed designers have some training but not the accumulated experience that an expert does. While Crismond and Adams (2012) based their matrix on design cognition research, they noted that “the social aspects of design, including the challenges of helping students develop their abilities to collaborate and cooperate

Table 1.
Design Cognition Taxonomies in Prior Literature from Strimel and Grubbs (2017).

General Design Process		**Practitioner Design Process**		**Cognitive Processing for Design**				
Technology Education Design Process Model (Welch, 1996)	**High School Engineering Design Process Model** (Hynes et al, 2011)	**Mental processes for technological problem solving** (Halfin, 1973)	**Engineering Textbook Design Process** (Moore et al., 1995)	**Cognitive Procedures in Solving Problems** (Middleton, 1998)	**Problem Domain: Degree of Abstraction** (Purcell, Gero, Edwards, & McNeill, 1996)	**Strategy Classification Scheme** (Purcell, Gero, Edwards, & McNeil, 1996)	**Function-Behavior-Structure** (Gero & Kannengiesser, 2004)	
Reading the Design Brief	Identify Need or Problem	Analyzing	Problem Definition	Generation: Retrieval	System	Analyzing the Problem	Design Requirement	Formulation
Discussing Performance Criteria	Research Need or Problem	Communicating	Gather Information	Generation: Synthesis	Subsystems	Consulting Information about the Problem	Function	Synthesis
Discussing Constrains	Develop Possible Solution(s)	Computing	Generating Ideas	Generation: Transformation	Detail	Evaluating the Problem	Behavior Expected	Analysis
Generating Possible Solution	Select Best Possible Solution(s)	Creating	Modeling	Exploration: Exploring Constraints		Postponing the Analysis of the Problem	Behavior from Structure	Evaluation
Sketching / Drawing a Possible Solution	Construct a Prototype	Defining Problem(s)	Feasibility Analysis	Exploration: Exploring Attributes		Proposing a Solution	Structure	Documentation
Planning the Making of a Mock-up	Test and Evaluate Solution(s)	Designing	Evaluation	Executive Control: Goal Setting		Clarifying a Solution	Description	Reformulation type 1
Manipulating Materials	Communicate the Solution(s)	Experimenting	Decision	Executive Control: Strategy Formulation		Retracting a Previous Design Decision		Reformulation type 2
Making a Mock-up	Redesign	Interpreting Data	Communication	Executive Control: Goal Switching		Making a Design Decision		Reformulation type 3
Refining a Mock-up	Completion (leaves the cycle)	Managing		Executive Control: Monitoring		Consulting External Information for Ideas		
Copying a Mock-up		Measuring		Executive Control: Evaluation		Postponing a Design Action		
Checking Available Resources and Materials		Modeling				Looking Ahead		
Abandon Current Solution		Model/Prototype Constructing				Looking Back		
Plan Making		Observing				Justifying a Proposed Solution		
Making a Prototype		Predicting				Analyzing a Proposed Solution		
Identifying a Problem with a Prototype		Questions/ Hypotheses				Postponing an Analysis Action		
Modifying the Prototype		Testing				Performing Calculations to Analyze a Proposed Solution		
Evaluation of a Possible Solution		Visualizing				Evaluating a Proposed Solution		
Evaluating of a Sketch or Drawing						Explicitly Referring to Application Knowledge		
Testing a Mock-up						Explicitly Referring to Domain Knowledge		
Evaluating a Mock-up						Explicitly Referring to Design Strategy		
Testing Prototype								
Evaluating Prototype								
Recording Results from a Mock-up								
Recording Results from a Prototype								

in design teams and learn through their interactions with peers…have not been articulated in this version of the framework" (p. 778).

The Borders of Design Cognition

As noted in the previous quotation, design is inherently social (Bucciarelli, 2003) whether that is through interactions with clients, stakeholders, or other team members. "Designs do not exist in a vacuum" (Todd Kelley & Rayala, 2011, p. 201). Depending on the context of the design problem, background knowledge in a variety of domains is useful; design educators also encourage students to cultivate knowledge through interviews and observations with potential users. By its social connections, design is also linked to societal and ethical issues (Jasanoff, 2016; Purzer & Chen, 2010), suggesting that the situation in which design occurs is important.

An analogy used in design literature gives another way that design is unaddressed by cognitive theories: the problem space and solution space. As designers work, they define what the problem space is—the task environment. Effective design traverses the boundaries of this problem space into the solution space—an area of potential solutions to the problem—and as these solutions are explored, the understanding and nature of the design problem space is changed (Cross, 1997; Dorst & Cross, 2001; Salustri, Eng, & Rogers, 2009). This dynamic representation of design spaces emphasizes that the situations of design, and designer perceptions and understanding of these spaces, make a great deal of difference in the generated solutions. The representation also illustrates that the approaches taken in design are determined by whether or not designers observe salient details of the design environment (Daly, Adams, & Bodner, 2012; Goel & Pirolli, 1992).

Adams et al. (2003) posed the question "what does design learning look like?" For example, they acknowledge design cognition investigations mentioned previously, and note that more experienced designers tend to lengthen the process, dig deeper into each phase, and flow through phases of design. However, the type of design problem provokes a different cognitive response and the authors give more complex windows on what design learning might look like including adaptive expertise and learning as a dynamic system. There is a present recognition that design expertise involves flexibility for different situations and effectively dealing with complex situations by using available resources.

Exploring Design as Situated Cognition

Given the mental nature of design activity and its simultaneous contextual dependence, situated cognition may be an appropriate framework for investigating design activity and learning. Situated cognition integrates knowing and doing and argues that environmental and sociocultural contexts impact learning (Driscoll, 2005). Therefore, our investigation explored the overarching question "What might design education and learning look like from a situated cognition perspective?" The objectives of the research included 1) identifying similarities between design practices and situated cognition and 2) synthesize implications for design education as a result of these similarities.

Method

To identify similarities between the concepts of design practice and situated cognition, a set of key dimensions was identified for each concept. Based on the descriptions of each dimension, areas of similarity were described on a matrix. Then, further information searching and synthesis were done to describe teaching and learning implications for the integration of design and situated cognition as *situated design cognition*.

The integration work of Crismond and Adams (2012) formed the dimensions of design used in this synthesis. After reviewing articles from more than 170 peer reviewed design journals, as well as books and anthologies on design, seven key design performance dimensions were identified as being central to doing design. The work of Crismond and Adams (2012) was selected for our integration effort because it involved a broad search and synthesis of design practice. Additionally, the dimensions represented are overarching characteristics of doing design and are supported by patterns of design cognition.

Next, the overview of situated cognition by Driscoll (2005) was selected to inform dimensions of situated cognition because it also provided comprehensive coverage of the concept. Situated cognition stems from the belief that "what people perceive, think, and do develops in a fundamentally social context" (p. 157). If we are not able to *do* as a result of what we know, or are not able to transfer what we have learned to new situations, the learning is not meaningful. The dimensions of situated cognition are organized around two overarching ideas provided by Driscoll (2005) to describe the nature of situated cognition: "knowledge is conceived as lived practice" and "learning is participation in communities" (p. 153). Beneath these two ideas are five ways in which situated cognition is realized.

Dimensions of Design Practices

Learning while designing. Effective design is a process of learning. Each phase of the design process (e.g., problem definition, brainstorming, prototyping, testing) is informational and should inform deliberate iteration. Supporting this dimension, a study of high school student design cognition by Strimel (2014b) found that participants who enacted more iterations for testing their solutions, making observations, interpreting the outcome data, and using the resulting data to make design optimizations achieved better solution performance results. Furthermore, Wankat and Oreovicz (1993) state that expert problem solvers often evaluate any mistakes or failures in the design process to learn what should have been done and then develop new problem solving methods, while novices will often ignore the failures or mistakes made.

Making and explaining knowledge-driven decisions. Building on information obtained through research in the design process, effective designers conduct tests and generate insight as a foundation for their decisions. Additionally, effective designers give rationales for their decisions (Jackson, Mentzer, & Zissimopoulos, 2015). For example, Strimel (2014b) found that high school participants who conducted tests to assess different design ideas, and interpreted the resulting data to inform design decisions, developed more effective solutions.

Working creatively to generate design insights and solutions. Creativity and innovation are key objectives of design education. Facione (2011) describes that "creative or innovative thinking is the kind of thinking that leads to new insights, novel approaches, fresh perspectives, and whole new ways of understanding and conceiving of things" (p. 14). The National Academy of Engineering and National Research Council (2009) state that creativity is inherent in the engineering design process and therefore, include creativity as one of the engineering habits of mind. In addition, this dimension of effective design includes being able to deal with ambiguity or uncertainty in the design process.

Perceiving and taking perspectives intelligently. As designers collaborate with team members and potential users, the skill of empathy can broaden their understanding of the problem and help identify greater potential solutions. Fila and Hess (2014) posit, "empathic skills such as understanding user needs within their own surrounding context are seen as essential to developing appropriate and innovative designs" (p. 2). These interactions with people provide an opportunity to learn from others, which effective designers will use to their advantage in developing successful design.

Conducting sustained technological investigations. Much of design is object-based and therefore, the analysis of resulting design artifacts is important. As a result, effective design can involve the use of conjectures or propositions, and rigorous testing of design artifacts and their potentials. As stated by Orr and Flowers (2014), sustained investigations are the way in which people learn and inform their future problem solving judgments.

Using design strategies effectively. Given the wealth of information and possibilities in design, effective designers know how to manage, synthesize, and apply a range of techniques. They have an understanding of the design process beyond the needs of any one project (Lawson & Dorst, 2009) and are able to manage constraints or criteria of the given situations.

Integrating and reflecting on knowledge and skills. Effective design enables and is enhanced by reflective practice (Schön, 1983). This type of metacognition can help designers foresee and overcome roadblocks in design. Therefore, metacognitive thinking skills are considered essential for success as a technical problem solver (Todd Kelley, 2008).

Dimensions of Situated Cognition

Knowledge as lived practice. The first overarching characteristic of situated cognition is that it involves lived practice. "One learns a subject matter by doing what experts in that subject matter do" (Driscoll, 2005, p. 156); said again, our "understanding is embodied through [our] actions" (Daly et al., 2012, p. 210). Dall'Alba (2009) similarly notes, "Becoming a professional, then, involves transformation of the self through embodying the routines and traditions of the profession in question" (p. 37). Part of the learning process, and a simultaneous demonstration of learning, is the use of expert behavioral patterns and resources. In the context of design, as we learn effective design we begin to mirror the behavior of experts. Situated cognition is focused on this applied—instead of inert—knowledge.

Anchored instruction. Situated cognition implies that instruction is grounded in real-life contexts. Learning tasks are based on practical situations (even if they may not be encountered by the students) and embedded data which is used to solve the problem (Choi & Hannafin, 1995). The authenticity of these contexts enables students to do and apply knowledge, rather than recite (Strimel, 2014a).

Assessment in-situ. Like anchored instruction, situated assessment is based on real situations, evidence of doing, and evidence of participation in a community. Instead of tests, which are limited in their realism and interactivity, assessment methods could include portfolios, process data, or performances. These alternative methods are more in line with the situated learning processes of doing and interacting.

Learning as participation. The second overarching characteristic is that learning is a reciprocal connection with community. On the one hand, we learn through interaction with experts and by adopting their behavior; these experts are the core members of the community. On the other hand, learning co-constitutes the community (Driscoll, 2005, p. 159), every member is changed; our interactions can help in "defining and redefining the very nature of the profession" (Lawson & Dorst, 2009, p. 66). Throughout these interactions, learning is evidenced by increasing participation—a beginner might observe the community while someone with more practice can engage with the community.

Communities of practice. Choi and Hannafin (1995) stated that effective situated learning tasks should be "coherent, meaningful, and purposeful activities that represent the *ordinary practices of a culture*" (p. 56, emphasis added). Practitioners and experts are bound by their common engagement with these activities, called a community of practice (Barab & Duffy, 2000). Communities of practice collaborate to solve problems. Importantly for newcomers, communities govern access to resources; membership in the community is obtained by participation.

Apprenticeships or cognitive apprenticeships. The focus on apprenticeships in situated cognition is based on the real-life learning of many professions. Learning happens through incipient participation with a master, even in menial tasks, and observation of the situation. The role and responsibilities of the apprentice eventually grow, demonstrating learning.

Semiosis. As communities grow and shift, the language and iconic representation of the community will develop. Semiosis, or sign-making and interpreting, is based on the inner-group communication that emerges and affords distributed intelligence of the community. Understanding the language of the community further enables access to community knowledge and resources.

Identifying Intersections of Design and Situated Cognition

Areas of overlap between design and situated cognition were identified by placing the dimensions orthogonally. Similarities, or areas where situated cognition might offer a new insight to design, were marked in the matrix. The Matrix of Informed Design, created by Crismond and Adams (2012), is intended to be used as a point of reference for future research, it is representative of key dimensions of design, and its descriptions are sufficiently ambiguous to afford new perspectives on design. We followed this model when describing the intersections of design practice and situated cognition: our matrix is a point of reference, representative of key aspects of the intersection of design and situated cognition, and open to new perspectives on design. To substantiate the areas of intersection between design and situated cognition, themes from prior literature were identified and implications for teaching practice were collected. Unpacking these intersections works to complete an image of situated design cognition.

Results

The overlapping dimensions of design and situated cognition are marked in Table 2 with a description of how situated cognition might enable or facilitate design practice. We took each element of situated cognition and envisioned what design might look like as enacted through that lens. The nature of situated cognition—that learning "is a natural by-product of individuals engaged within contexts" (Choi & Hannafin, 1995, p. 53)—supports the use of situated cognition elements to facilitate engagement in design and, consequently, effective design practice. Learning occurs as students integrate knowing and acting and being (Dall'Alba, 2009, p. 43); by embedding students in design situations to be solved, design students will learn through their practice of design. And the structures of situated design cognition are related to design or design-based strategies. Following the brief synopsis in Table 2, the intersection of situated cognition and design practice is described further. Empirical evidence and recommendations are provided where possible, though the completion of this vision is an opportunity for future research.

Anchored Instruction

Anchored instruction is similar to problem-based learning (Choi & Hannafin, 1995); this makes anchored instruction highly relevant for design education, since design- and problem-based scenarios are also similar. Among aspects of anchored instruction, the information-rich and meaningful context it provides might be effectively leveraged for design instruction. *Making Knowledge-Driven Decisions*, *Working Creatively to Generate Design Insights*, and *Perceiving and Taking Perspectives Intelligently* were all identified as areas of overlap for anchored instruction because an anchored approach brings embedded information and assumptions suitable for the design process. These anchored situations enable students to bring their own perspective on the problem, or reframe the problem as necessary, to generate different design approaches and solutions (Daly et al., 2012).

Table 2.

Intersection Matrix of Design and Situated Cognition.

	Knowledge as Lived Practice		Learning as Participation in Communities		
Dimensions of Informed Design	**Anchored Instruction**	**Assessment In-Situ**	**Communities of Practice**	**Apprenticeships/Cognitive Apprenticeships**	**Semiosis: Sign Interpretation and Production**
Learning While Designing	Refer to and learn from the design context while designing	Formative and summative feedback on design should improve practice	Peer collaboration informs design; learning is interactive	Effective design behavior is modeled by experts or peers	Comprehension of the evolving language of a community enables access and use of community knowledge and resources
Making Knowledge-Driven Decisions	Decisions are based on authentic problem contexts and users	Continuing evaluation of design decisions and gathered information; using decision rationales in assessment	Leverage the knowledge and resources of the community for decision-making	Observe experts or peers to understand value structures used in decision making and rationales	Language informs making and communicating decisions
Working Creatively to Generate Design Insights and Solutions	Evolved understanding of the problem can be used to generate insights	Feedback can be incorporated to generate and improve design solutions	Build off of the insights of others to generate and improve design ideas	Ideation and creative thinking processes can be learned through observation	Sketching ideas using the proper language and symbols can help a community envision new solutions
Perceiving and Taking Perspectives Intelligently	Design should be informed by the perspectives of authentic users/customers	Design should be shaped by user testing and feedback	Design should be informed by the standard practices of the culture in which it is situated	Observing experts can showcase the coherent, meaningful, and purposeful design activities that represent the practices of a profession	Community language can enable effective design communication among stakeholders; language provides access to the distributed intelligence of the community
Conducting Sustained Technological Investigations	Examinations of authentic design artifacts can inform design decisions	Rigorous and authentic evaluations of design concepts or artifacts can enable design optimization	Information sharing among the community can afford deeper investigations into innovative design solutions	Design critiques should be informed by the specific practices or standards various professions hold for evaluating design performance	The language of the community is used to effectively share design concepts and artifacts
Using Design Strategies Effectively	Experiences in authentic design tasks build a repertoire of knowledge and skills to be used in future design work	Understanding the outcomes of previous design experiences can build associations between design situations and effective strategies	Professional mentor guidance and peer feedback can aid in the selection of an effective design strategy	Expert critiques of designs can provide suggestions for both solution and process improvement	Design strategies that use community language can help to leverage the distributed intelligence of the community
Connecting and Reflecting on Knowledge and Skills	Metacognitive regulation can enable the acquisition of knowledge and skills necessary to complete a design task	Design assessment incorporating self-reflection can identify the knowledge and skills necessary to better solve a problem	Analysis of peer design performance can be used as learning and self-reflection tool	Observing experts can highlight common design attributes such as creativity, focusing on the end user, metacognition, collaboration, and intellectual curiosity	Notebooks, design artifacts, and design process visualization can be used as reflective tools

Young (1993) outlined four steps for setting up authentic, anchored instruction: pick an appropriate set of situations, determine necessary scaffolding, find supports to track student progress and guide students, and define the role of assessment. These steps are also useful for design—the small design challenges or large design projects in a course should be grounded in realistic scenarios that enable multiple perspectives of analysis. The instruction might be scaffolded so that students grow in confidence during the design projects, as they experience success on the initial ones (Jobst et al., 2012; Tom Kelley & Kelley, 2013).

Several guiding activities related to design have recently been proposed. For example, Atman, McDonnell, Campbell, Borgford-Parnell, and Turns (2015) tasked students to analyze their own design process timeline as a reflective tool to foster understanding of the design process. Also, Purzer (2011) similarly proposed the analysis of other design teams as an opportunity for team reflection the design process. Reflection like this may enable students to guide their own progress throughout the design challenge. Because the reflection is based on authentic situations, learned design strategies can be applied to similar situations in the future. Young (1993) finally recommended ongoing, integrated assessment for situated learning; this approach for design might require frequent design checks with the instructor, teacher access to design journals (which can easily be done through electronic design notebooks), or assessment of engagement and interaction with the design situation.

Assessment In-Situ

Assessment remains a challenge in design (Strimel, Bartholomew, Jackson, Grubbs, & Bates, 2017). The ambiguity of the process, availability of multiple correct approaches, and potential for multiple solutions can lead to unreliable results. Approaches to assessment from a situated cognition perspective may address some of these assessment challenges for design educators. Several types of assessment are mentioned for situated cognition and the focus is on realistic connection between enacted knowledge. Multiple choice tests, for example, are not part of many professions. Options for assessment include diagnostics, summary statistics, and portfolios (Driscoll, 2005); self-referencing information, performance assessment, and concept maps (Choi & Hannafin, 1995); or log files showing engagement with content (Jonassen & Land, 2000).

As a design educator it is important to ask what is emphasized for design assessment. Design education may help enable critical thinking and communication skills (Cross, 1982), but does the focus need to be on these skills? creativity? design performance? Assessment methods should align with these priorities; be based on design performance, not esoteric knowledge; and enable students to reflect and improve their design practice. Feedback from assessment procedures and testing conducted while designing can provide deeper insight into designed ideas. Substantive improvements to the design product should also develop from the instructor’s and users’ feedback—a form of assessment beyond the design classroom.

Communities of Practice

Community classrooms require a shift in the nature of our classes, decentralizing decision-making from a teacher-centered to a student-centered approach. Participants in a community of practice include those who are inbound, insiders, outbound, or boundary members (Driscoll, 2005). Insiders are especially able to shape the culture of the community, though it is influenced by the participants as a whole.

Community of practice approaches in design education provide access to a central set of stakeholders and shared resources. With regard to information searching and benchmarking, important design steps, community of practice teaching would imply information sharing rather than everyone repeating the same steps (Collins, Joseph, & Bielaczyc, 2004). Depending on the design situation, the learning community may rely on boundary members who are able to bridge the classroom and the design domain of interest. For example, certain stakeholders might enable access to users or domain specific knowledge.

Treating collaborative groups within the class as design communities of practice may also yield new insights for situated design cognition. For example, grouping students based on interest in a design problem may be a benefit if they are able to form an effective community (and instructional design may be set up to facilitate such a community formation). Inter-group check-ins between the classroom learning communities, or design teams, may also allow students to give one another feedback and guidance in the design process.

Apprenticeship

Apprenticeship models are familiar for design education because effective design behavior is often modeled by expert instructors or peers during design critiques. Cross (2006) stated

> What designers know about their own problem-solving processes remains largely tacit knowledge—i.e., they know it in the same way that a skilled person 'knows' how to perform that skill. They find it difficult to externalize their knowledge, and hence design education is forced to rely so heavily on an apprenticeship system of learning. (p. 9)

Because design is ambiguous, design education has often relied on apprenticeships of sorts. This helps uncover the reason for design decisions and makes apparent the salient feature of a design problem in case the student had missed them.

A dialogue observed by Schön (1983) demonstrates the ways that design instructors might model behavior: the design teacher thinks-aloud, modeling decision-making for the student in response to constraints of the design situation. This thinking-aloud demonstrates knowing in action and tacit knowledge, potentially touching on an array of design motives and skills.

Semiosis

The final element of situated cognition involves the language used by designers. Several types of communication are evident at various stages of design: verbal, graphical, mathematical, or even physical models are used to communicate the features of design (Dym et al., 2005). Sketching is an important part of design and can be used in many phases of design, including problem definition, brainstorming, and communication (Cardella et al., 2006). Simple sketches, with eliminated detail, present ambiguity and enable the design team to envision new solutions as they go (Tversky & Suwa, 2009).

The nature of community language suggests that in order to have a deep understanding of design artifacts or sketches, one needs to be part of the community—or at least have access to the resources of the community. This has implications for design assessment, since the ideas embedded in a sketch or representation can never be fully unpacked. Design educators should keep this in mind when attempting to interpret design journals or documentation. Sketching also has implications for reflection during design; if ambiguity is preserved and sketches are revisited, it may lead to new insights in design.

Conclusion

Much of design education and practice already demonstrates the belief that designers' actions are grounded in situations, contexts, or frames of thinking, and that designers' interactions with the environment and others fundamentally change the design problem and solution spaces. "Design Thinking reproduces knowledge through action with the goal of changing existing situations into preferred ones. These challenges are tackled in interdisciplinary teams with a clear focus" (Noweski et al., 2012, p. 79). Existing perspectives on design cognition have enjoyed a strong discourse and further support through empirical inquiry. The perspective presented in this framework should be further triangulated by similar discourse and experimentation related to each element of situated design cognition. The five situated cognition elements are main elements drawn from a limited portion of rich literature on instructional design; therefore, this matrix might be expanded in the future to encompass more facets of situated cognition.

Nonetheless, this paper has distilled situated cognition to five key elements and described its alignment with design practice. Each dimension of situated cognition represents a lens by which we might view design education for enhancement, bringing the strengths of learning theories to our field. Whether in design education courses, or for instructors using design-based learning, aspects of the emergent *situated design cognition* seem to point the structure of our learning environments toward authentic and collaborative problem-solving. The implications of situated design cognition hold promise for fostering engaging contexts for learning. While some of these implications are found from previous literature, there are many starting points in this matrix that can be expanded by further literature searching, empirical investigation, and theory building, hopefully leading to new implications in design teaching and learning.

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