Sketching Design Thinking: Representations of design in education and practice

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RESEARCH

Abstract
Research on design pedagogy has shown that students progress through a variety of barriers on the path to becoming a successful design practitioner, and that frameworks for explicit reflection can be beneficial to the development of design students. Schön uses the concept of reflection-on- action to describe one form of reflection on design practice, with the eventual goal of improving design processes and judgment. In this study, sketching is used as a form of reflection-on-action in a first semester intensive course in interaction design (IxD). This sketch reflects the student's current understanding of the "whole game" or holistic view of design in IxD. Current practitioners in IxD companies were asked to draw the "whole game" sketch as well. Parallels among the sketches and areas of divergence are discussed. In summary, students shifted from abstract, linear representations of process early in the semester to more concrete, iterative representations by the end of their first semester. Practitioner sketches were more abstract and linear, but also included representations of business terminology and design teams. We propose a preliminary model of change in expertise, which documents the shift in a designer's visual representation of their process as their expertise increases over time. Implications for changes in design pedagogy and avenues for future research are discussed. (210 words)

Key words
reflection, sketching, human-computer interaction (HCI), design practice

Introduction

Reflection has long been implemented as a feature of educational practice, both in mainstream education (Rogers, 2001) and in design education (Ellmers, 2006; Schön, 1983, 1985). Reflection as a classroom activity is often centered on journaling, blogging, discussion forums, or post-hoc evaluation of projects, and is generally discursively focused on documenting the past and present. While various forms of reflection prompts have been used to stimulate thinking – ranging from abstract to concrete – these prompts can be seen as an integrated measure of the overall curriculum, intended to stimulate individual thinking around synthesis, and to provide an additional evaluative measure of student performance.

In this paper, we will structure our discussion around visual forms of reflection applied as an evaluative measure to design students and practitioners. These reflections focus on a holistic way of thinking about a discipline (Perkins, 2010) and the student's relationship to that discipline. The process of reflection is also treated as an evaluative measure that can be used in conjunction with models of design expertise (Dreyfus, 1981; Lawson and Dorst, 2009) and schemas or processes (Dubberly, 2004; Nelson and Stolterman, 2012) to understand what and how the student or practitioner is thinking about design – what they prioritize in their process and how they visually represent these elements.

The "Whole Game"

The concept of "playing the whole game" is derived from Perkins (2010), who notes the importance of viewing education in a holistic, action-driven way. Rather than teaching components of a process without putting it together (described as "elementitis") or learning "about" a subject without ever applying it, students learn through the process of engaging in the activity. This approach melds with Schön's conception of the design studio – a place where education and praxis are linked – in a profound way.

In educating non-designers (or non-traditional designers), it is vital to keep a clear conception of the terminal objective of design education: preparing students to become successful design practitioners (Brandt, Cennamo, Douglas, Vernon, McGrath, and Reimer, 2011; Shaffer, 2003). Assuming this terminal objective, understanding the connections between the realities of practice and the pedagogy that links the student to future practice is critical.

Reflection-on-Action

Schön (1983) discusses the role of reflection in education and practice, noting the complementary roles of reflection-in-action and reflection-on-action. Reflection-in-action is a tacit process whereby the designer considers and evaluates available information to make a design decision "in the moment." In contrast, reflection-on – action is an explicit act, whereby the designer formally reflects on a designed artifact, experience, or process (Schön 1983, 1987). Both processes are critical to the functioning of the studio mode of education – the former as a habit of the

individual designer in building their design judgment, and the latter in understanding design practice in a more abstract, meta-cognitive sense. This study addresses the role of formal reflection – or reflection-on-action – in design education and practice as a tool for stimulating tacit reflection on processes, beliefs, and tools.

Modeling of Expertise

In studying various levels of competence in design practitioners, expertise becomes a significant concern. Dreyfus (1981) proposed a generic model of expertise, spanning from novice to expert. These five stages include: novice, advanced beginner, competence, proficiency, and expertise (Dreyfus, 1981). In a more recent version of this model, Dreyfus (2003) extended this work to include six stages: "novice, advanced beginner, competent, expert, master, and visionary" (quoted from Lawson and Dorst, 2008:98). These levels suggest, from a perspective of generic expertise, that as a designer increases in competence, their overall awareness of their design actions decreases, with informed intuition taking the place of explicit rules or directed patterns of thinking. Meyer and Land (2003) also argue for this evolution based on expertise through their notion of "threshold concepts." In this framework, the authors posit that once core concepts of a discipline are learned, they transform the individual and are largely irreversible – "the change of perspective occasioned by acquisition of a threshold concept is unlikely to be forgotten, or will be unlearned only by considerable effort." (Meyer and Land, 2003: 416). Taking these two views of expertise and learning together, along with work done explicitly within the domain of HCI (Siegel andStolterman, 2008), it seems that an increase in design expertise decreases awareness of design decisions, and may lead to a holistic picture of practice, rather than a comprehensive, detailed process.

Methods

This study is informed by the artifacts of educational and professional practice, using *reflection-on-action* to reveal patterns of thinking about design. The "whole game" sketch can be seen as a diagnostic tool that makes tacit assumptions about process explicit, and allows the design practitioner or beginning design student to build and reflect on their process as a developing schema (Nelson and Stolterman, 2012), engaging in explicit and tacit reflection.

Data Collection

The data for this study is drawn from two primary sources: the pictorial reflections of beginning interaction design students, and the reflections of interaction design practitioners working in the field.

Student Reflections

Student reflections were captured from an immersive first-semester course in the Master's-level Human-Computer Interaction design (HCI/d) program at a large Midwestern United States university. Students were asked to complete a "whole game" sketch at three points in the semester: during the first, fifth, and fifteenth week in order to provide the instructor an idea of what kind of schema students were generating as they progressed through the course. These sketches were a required assignment, and were requested from students using the following prompt:

> ***First Sketch****: "Draw a picture of the "whole game" of HCI design. Do not do research on this! Draw what is your intuition and understanding today."*
>
> ***Second and Third Sketches****: "Each person must draw and submit a picture of the whole game of HCI design. You may discuss your diagram with others, but it should be your picture in the end. This is your current understanding of how to "play the game" of HCI design."*

No constraints in terms of size, components, or medium were imposed. The course enrollment during the semester of data collection was approximately 60 students, comprising undergraduate students (taking a cross-listed course), Master's students in the HCI/d program, and graduate students from other programs taking this course as an elective or program minor. HCI/d Master's students represented approximately 60% of the course roster, and this ratio is reflected in the final set of reflection sketches selected for analysis. The HCI/d program, in particular, recruits students from backgrounds that would be considered non-traditional for design education, including computer science, sociology, education, journalism, and cognitive science.

Practitioner Reflections

Interaction design practitioners were selected to be interviewed as part of a larger study. Six practitioners representing six different companies were recruited. These companies included interaction design (IxD) consultancies, IxD agencies within larger companies, and web startups. The practitioners had a range of 4-20 years of experience; one was a graduate of the same HCI/d program as the student participants, and all worked in interaction design, user experience design, or user research. During the course of a larger interview, each practitioner was asked to describe their process or "whole game" which they sketched on paper or a whiteboard:

"Draw a picture of your design process as it actually occurs versus how you might portray it to a potential client. We're interested in a picture of [company name's] design reality."

Analysis

Student Reflections

Student reflections were analyzed as intact sets, with all three sketches from each student grouped together to be evaluated as an evolutionary sequence. Each set was then iteratively sorted based on formal characteristics and organizational paradigms (e.g., flowchart, storyboard, naturalistic sketch, word cloud). From these initial categories, 16 sets were selected from these provisional categories for further evaluation and analysis, and were chosen to represent the variety of formal and textual elements of the entire data set. These 16 sets represent the approximate ratio of undergraduate, graduate, and graduate HCI/d students present in the course, and were also balanced for gender and ethnicity. The findings that follow are based on themes observed across all sets of student reflections, but examples are limited to these 16 sets for simplicity.

Formal and conceptual characteristics were used to code each reflection sketch, including: organizational style, tools used, number of nodes, terminology, connectedness/ iteration, and sequence (see Table 1).

Practitioner Reflections

All six practitioner reflections were evaluated in isolation from the student reflections, then all reflections were evaluated together to form a cohesive system of characteristics. These combined characteristics are presented in Table 1.

Findings

The findings from the student and practitioner reflections are presented separately. Student reflections are documented by a longitudinal grouping of sketches, as well as an evolutionary sequence.

Student Reflections

A wide range of student perspectives, skill levels, and views on design are represented in the reflection sketches chosen for analysis. Ten of the selected sets were from HCI/d Master's students, 3 were non-HCI/d graduate students, and 3 were undergraduate students. Each sequential set of sketches (e.g., first round, second round,

Organizational Style	Flowchart Word Cloud Concept Map Storyboard Naturalistic Sketch
Tools Used	Pen Pencil Colored Marker Crayon/Pastel Whiteboard/Dry Erase Marker
Number of Nodes	4 to 100+
Terminology	Tools (e.g., Axure, Omnigraffle) Data (e.g., interview, empirical) Concepts (e.g., readability, usability, the problem) Activities (e.g., usability testing, coding, development, sketching) People (e.g., boss, user, designer)
Connectedness/ Iteration	Single arrow Bi-directional arrow Iterative arrow (arrows pointing to multiple points in a process, forming a loop) Stacked elements Holistic
Sequence	Linear Amorphous (no clear beginning or end) Concept map (clear beginning, but no clear end)

Table 1. Emergent characteristics used to code student and practitioner reflections.

third round) was evaluated separately, using the coding system presented in Table 1.

First round

In the first round, a wide range of interpretations of the "whole game" sketch were observed. From the utter simplicity of Figure S1.1 – design as an abstract activity – to the post-apocalyptic interpretation of Figure S1.5. A range of approaches fit in between these two extremes, including many iterations on a linear process model (e.g., Figures S1.3, S1.4) or concept map (e.g., Figure S1.6). Terminology was generally focused on high-level, abstract concepts (e.g., research, prototyping, problem solving, design) or categories (e.g., design aesthetics, design research, methods, people). The number of nodes were relatively low, with a few exceptions (e.g., Figure S1.6), focusing on a simplified process (e.g., Figures S1.3, S1.4) or collection of related, yet disconnected concepts (e.g., Figure S1.7). In this first week of the course, students appeared to be grappling with the field of HCI, either as beginning designers in the most general sense, or designers approaching this field from another established design perspective (e.g., graphic design).

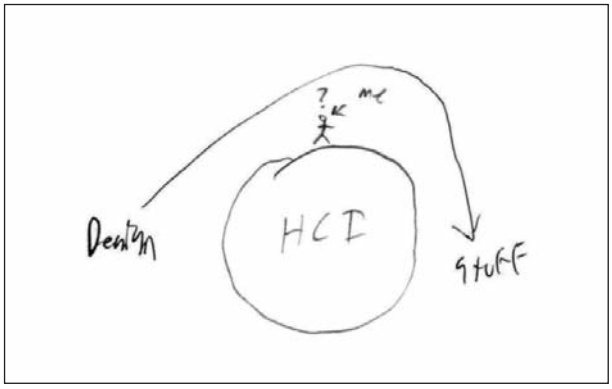

Figure S1.1. Student sketch, first round

Figure S1.2. Student sketch, first round

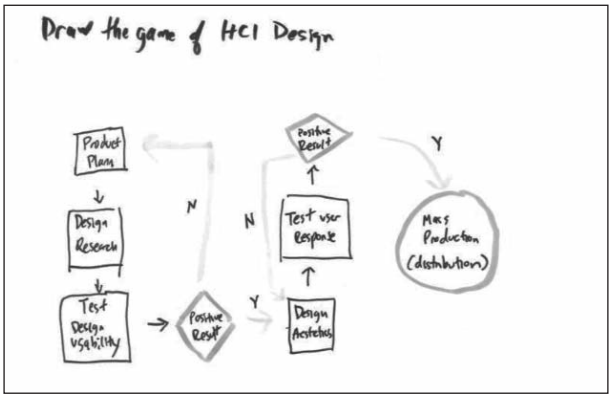

Figure S1.3. Student sketch, first round

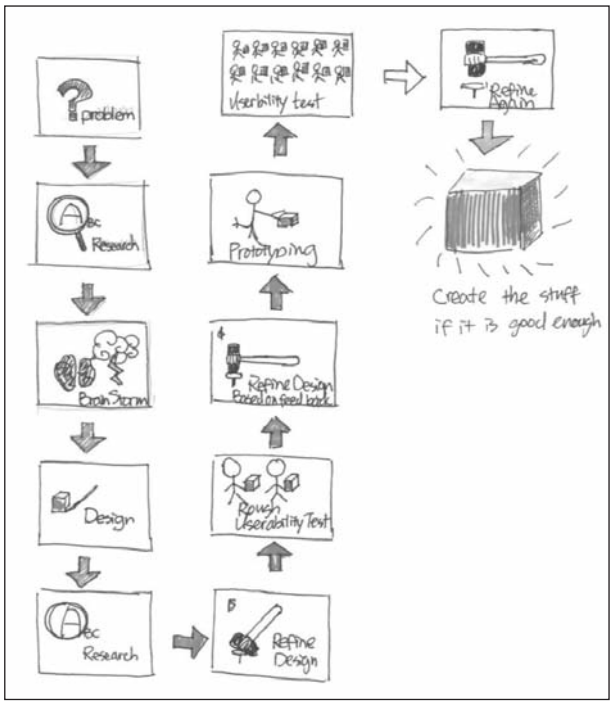

Figure S1.4. Student sketch, first round

Figure S1.5. Student sketch, first round

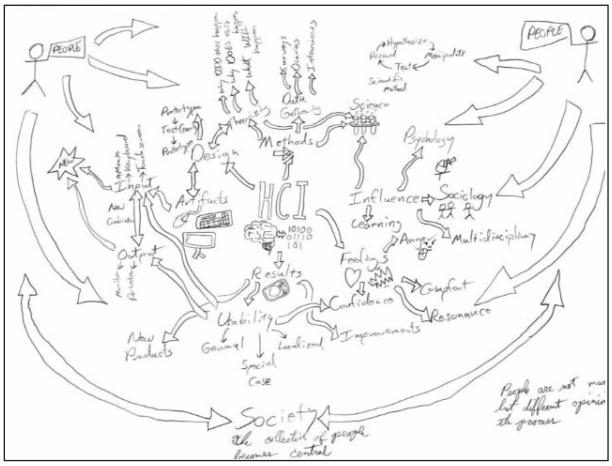

Figure S1.6. Student sketch, first round

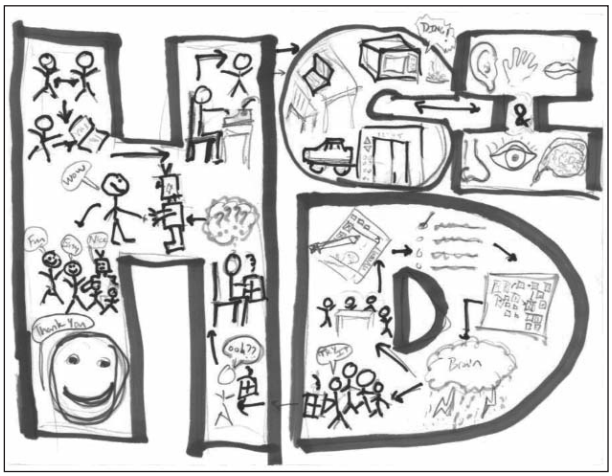

Figure S1.7. Student sketch, first round

Second round

In the second round, division between approaches became even more clear, with some choosing to continue to develop additional complexity within a linear paradigm (e.g., Figures S2.2, S2.4), while others moved to more iterative constructions (e.g., Figures S2.1, S2.5), and still others pictured their whole game in metaphorical terms (e.g., Figures S2. 3, S2.6, S2.7). This sketch was produced after the students had completed two significant design projects, and this stage in their education seemed to have an impact in these reflections. The more complex flowchart or concept map approaches attempted to document the influences that HCI draws upon (Figure S2.4) or the specific process steps that have been utilized in that student's design process (Figure S2.2). Meanwhile, other students recognized the iterative, interconnected nature of their process, represented in bi-directional arrows and looping (Figures S2.1, S2.5), even indicating where shortcuts may occur in the process (Figure S2.5).

Metaphorical interpretations of the "whole game" ranged from personas of various approaches with instructions to "form whatever story you'd like" (Figure S2.6) to a marker sketch of light in darkness (Figure S2.3) to a visualization of beauty in the "swamp" of designing (referencing Schön 1983).

Use of terminology was quite varied, but shifted slightly from abstractions (e.g., research, prototyping, problem solving) in the first phase to more concrete human activities (e.g., generate ideas, create solution, usability testing, production). This round also focused more strongly on elements of these various activities, including elements of group dynamics (e.g., mantra, peers, mentors) and methods (e.g., affinity diagramming, ethnography, usability testing). As the creator of (Figure S2.4) noted at this stage: "Right now I see complexity[.] This is where I am, vs. where I want to be."

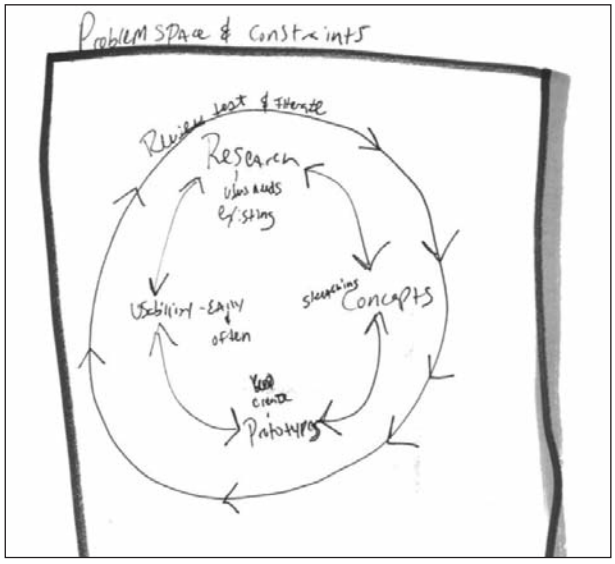

Figure S2.1. Student sketch, second round

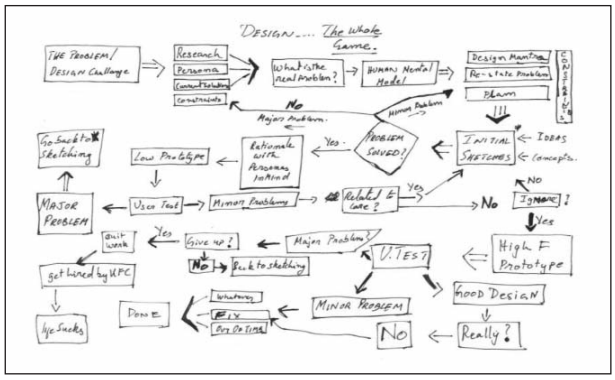

Figure S2.2. Student sketch, second round

Figure S2.3. Student sketch, second round

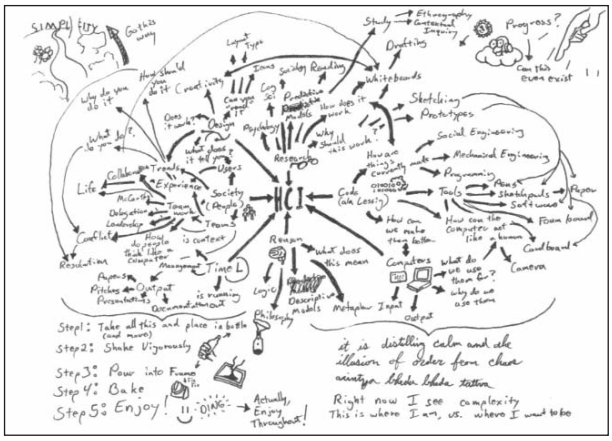

Figure S2.4. Student sketch, second round

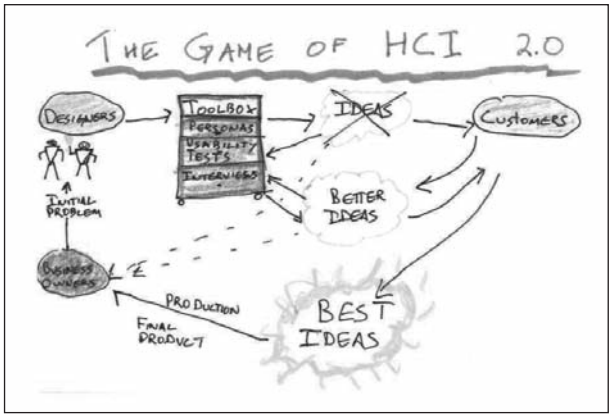

Figure S2.5. Student sketch, second round

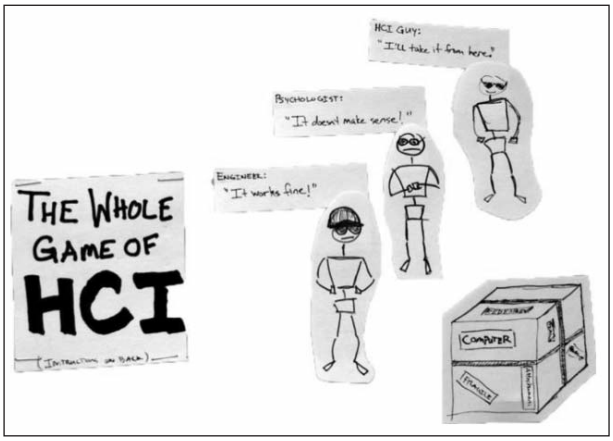

Figure S2.6. Student sketch, second round

Figure S2.7. Student sketch, second round

Third round

In the third round, sketches made an even bigger leap to concrete representations of the design process, grounded in human activities and complex in presentation of process. These reflections were often more narrative in quality than previous rounds, presented as a series of storyboards (e.g., Figures S3.1, S3.5) or as a metaphorical journey (e.g., Figures S3.2, S3.3). Some sketches included a more abstracted component of process, either as a parallel attempt to explain their process (e.g., Figures S3.4, S3.7) or as a reductive mantra (e.g., Figure S3.6). Terminology followed the trends of round two sketches, with a utilization of concrete activities (or categories of concrete activities), seemingly to represent various parts of the lived experience of the individual designer. These reflections were highly connected, either in proximal relationships (e.g., the stacking of Figures S3.1 and S3.3) or in overt connectivity (e.g., Figure S3.2). Some sketches represented a sense of linearity, but often drawn as a cycle or iterative loop (e.g., Figures S3.4, S3.5, S3.6), as compared with the precise beginning/end construction of round one.

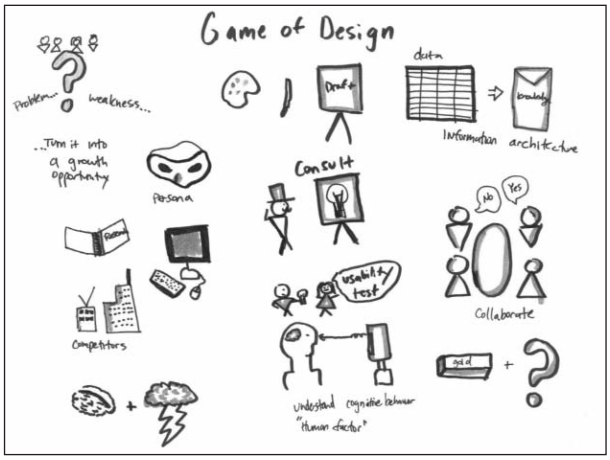

Figure S3.1. Student sketch, third round

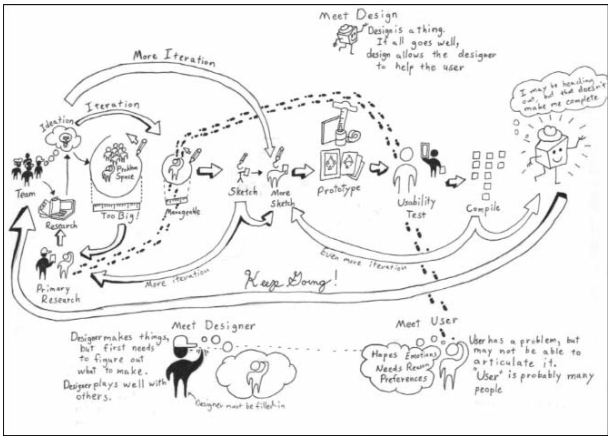

Figure S3.2. Student sketch, third round

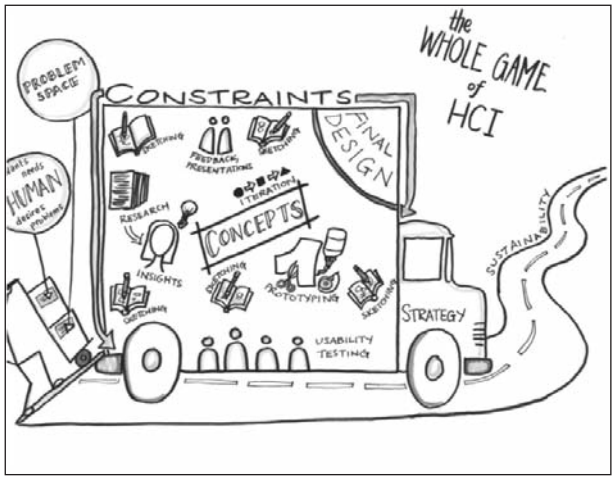

Figure S3.3. Student sketch, third round

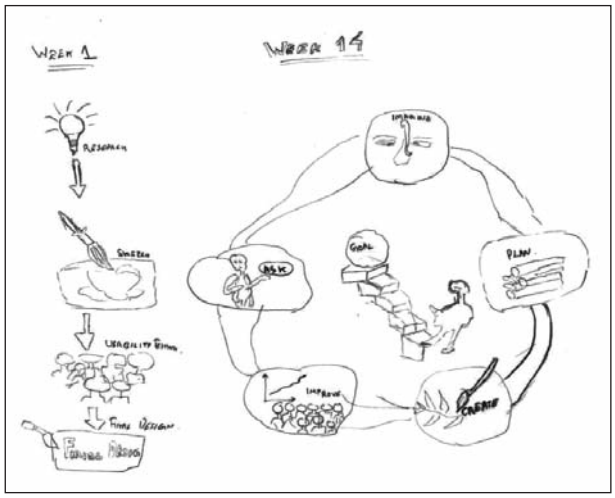

Figure S3.4. Student sketch, third round

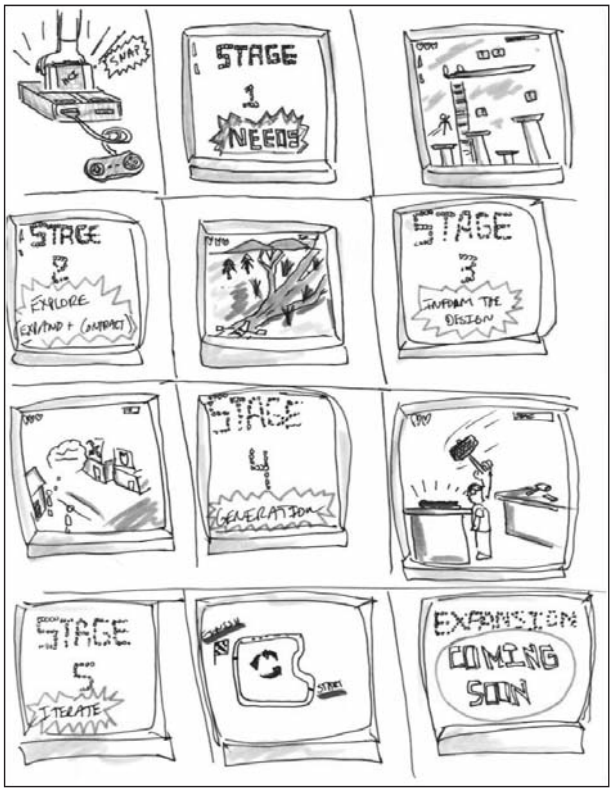

Figure S3.5. Student sketch, third round

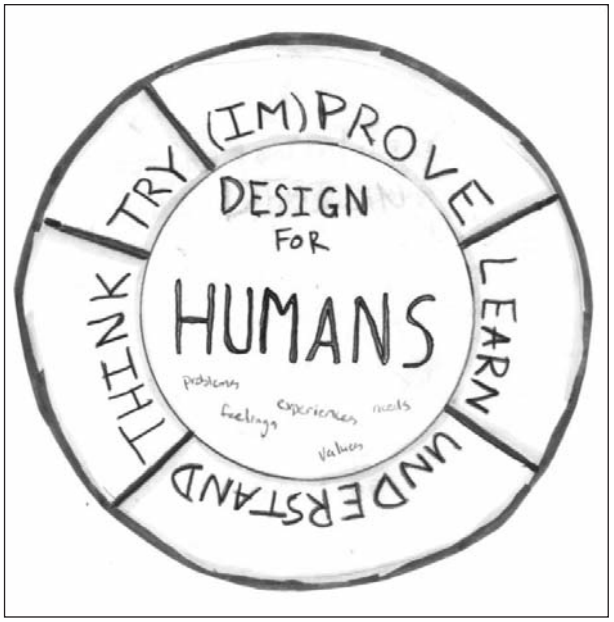

Figure S3.6. Student sketch, third round

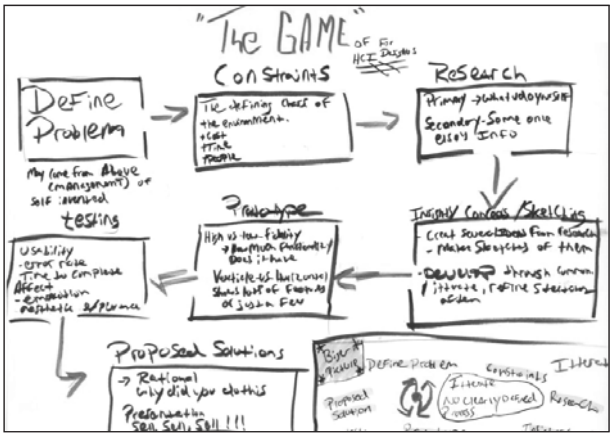

Figure S3.7. Student sketch, third round

Practitioner Reflections

The practitioner reflection sketches were completed in real time, as a way of discussing processes and methods used in everyday practice. Therefore, they reflect more immediacy, both in execution and in lack of planning or preparation. These sketches represent a wide variety of stylistic choices and organizational paradigms, with the majority drawn on a whiteboard and the remainder completed using a ready-at- hand sketchbook.

All of these sketches represented chaos, messiness of process, or uncertainty using visual and/or textual devices (similar to formal representations in Dubberly, 2004). These representations ranged from layering of lines and artifacts (Figures P1, P3, P6) to visual expansion of space (Figure P5) to textual cues (Figures P2, P4). Interestingly, these sketches were relatively simple, with the most complicated sketches containing less than 30 nodes. Complexity was implied, however, in a number of ways, including: categories of work, references to the client relationship, and business justification for the final design.

Categories of work

While the first aspect of complexity—categories of work—was present in the student reflection sketches, it generally included work germane to design actions in particular, ignoring outside workflows or the involvement of other designers or management. In contrast, these sketches imply the entire lifecycle of the design process, including project management, collaboration with the design team, issues of oversight, and evaluation/validation of the final design.

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Client relationship

The majority of these sketches reinforce the importance of the client in the success of the overall design process. This ranges from design empathy (Figure P3) to engagement (Figure P4) to clients as the origin of the "assignment" or design problem (Figures P1, P2, P6). All of these references, often placed at multiple points in the process, ensure a sense of connectedness and communication between the design team and the client/stakeholders. This communication seems to range from internal responsibility and scheduling (roadmaps or scoping in Figure P1) to assessment (user testing in Figures P4, P5, P6) to engagement ("tell and show how to deliver things simpler in a future/current environment" in Figure P3).

Business justification

The relationship of business goals is less clear when looking at these sketches in isolation, but the difference is striking when comparing the scope and character of terminology in these sketches vis à vis student reflections. The majority of the terminology used in this set relates directly to team or management (producer, front-end, lead users, stakeholders, project manager, client), but also relates strongly to the work processes of the individual workplace (roadmapping, build, release, visual design, branding) that are invoked when discussing a general design process or approach.

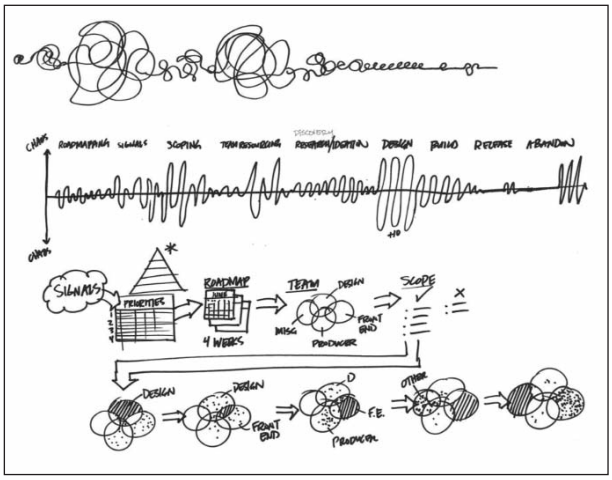

Figure P1. Practitioner sketch

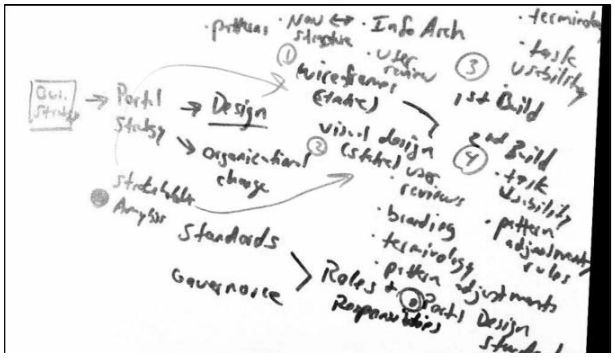

Figure P2. Practitioner sketch

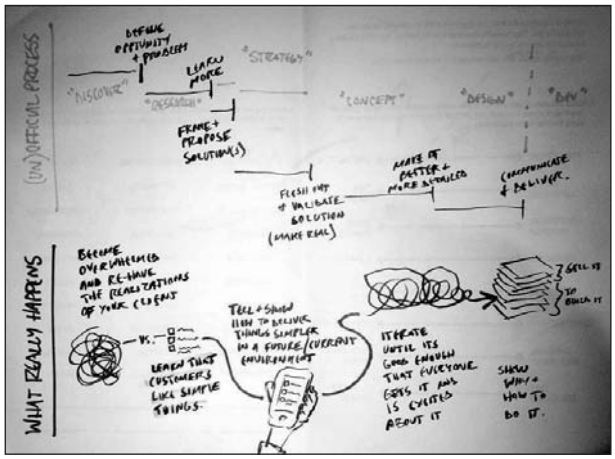

Figure P3. Practitioner sketch

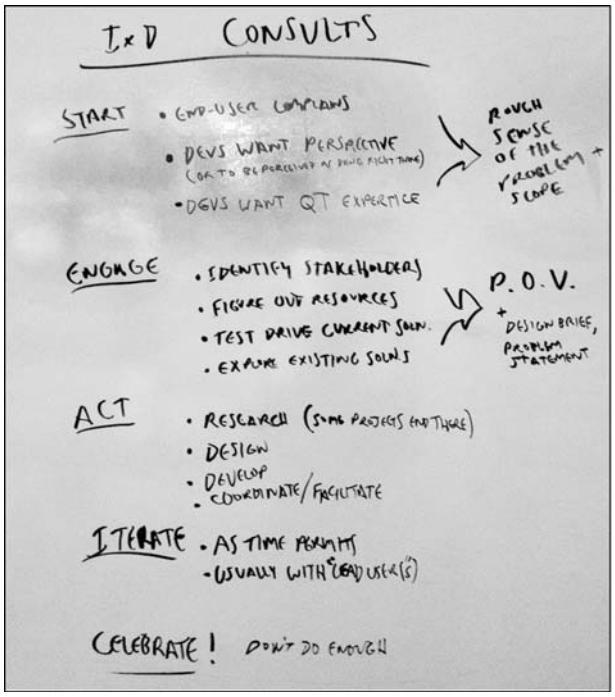

Figure P4. Practitioner sketch

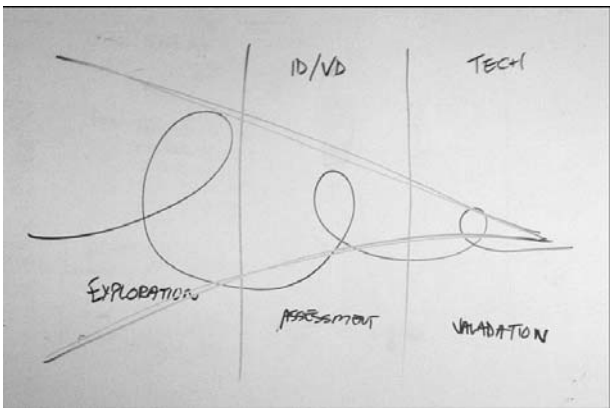

Figure P5. Practitioner sketch

Figure P6. Practitioner sketch

Discussion

There seems to be an effort from these beginning design students to re-compartmentalize, re-categorize, and re-synthesize their conceptions of design over time. This meta-cognitive reflection-on-action may indicate a general shift in their design thinking – in their thinking about design in general or design in the specific domain of HCI. A few general trends are apparent, including an increase in number of representative "nodes" as the semester progressed, a move from linear to cyclical/iterative representations, and a move from abstract/categorical terminology to concrete/task-centered terminology. This increase in concrete representation is consistent with a student confronted with messy, ill-structured problems, and could reflect the student's thinking about design in general. From an abstract notion of the practice of design with little grounding at the beginning of the semester, to concrete representations of actual design process informed by 4-5 large scale design projects completed in teams. This transition seems to indicate an increasing awareness of the scope of the design challenge, the inability to create a singular, comprehensive process model that incorporates all of their design activities, including the multiplicity of paths that may be used to lead to a design solution.

The practitioner sketches reflect the designerly identity of a hardened professional—action and results driven, with recognition of potential challenges and chaos that must be overcome during the design process. This description of a design practitioner is quite stark when compared to the risk-averse, simplistic representations of the student designers. Not only was chaos included and accepted in the design process (Figures P1, P3, P6), it was featured as a primary component. Unlike the student sketches, which gradually moved away from a linear model, almost all of the practitioner sketches were formed in some linear, directional way. This may reflect the importance of solution-focused design, or creating ideas that "ship" which drive professional IxD practice. The awareness of other designers and team members was also a significantly different between the student and practitioner sketches. While none of the student sketches comprehensively included other design team members (even though they worked on group projects) or clients, the practitioner sketches showed a high level of awareness of other collaborators in the design process, including engineers, graphic designers, marketing, sales, or management. This inclusion of business processes and multiple people involved in the design process is a critical element that seems to evolve over the period of design education or shortly after entering the workforce, but future work is needed to further clarify this development of a cross-disciplinary competency or awareness.

Synthesis of Student and Practitioner

Interestingly, when comparing practitioner and student reflection sketches, the practitioner sketches seem more in keeping with the early student sketches, rather than the late ones. The practitioners seem to explain their process in highly abstract, often business-laden terminology, using a definitively linear representation. Why is this seeming reversal of direction found in the student reflection sketches present?

We propose that an individual designer's representation of design, at least in a domain-specific sense, is bound to their level of design expertise (see Figure 1). Early in their socialization to design concepts, it is easy to view design in highly abstract, not- yet-explored terms. This conception is often linear, using categorical terminology to describe large sections of the design process. As the design student

becomes more familiar with design processes and methodologies common in their design field, they must adjust their process to account for the felt complexity of their process. This simultaneously becomes more iterative and "messy," while increasing in complexity and concreteness of activities, tools, or methods. As the student continues to mature as a designer, we propose that they develop an ability to synthesize this complexity into tacit design judgment; for example, "discovery" becomes a shorthand for a complex set of research techniques and processes, all contextually integrated in the practitioner's mind and practice. By the time these students become design practitioners, we expect they will return to relatively abstract, linear representations of design, even though their design activities represent the more complex, iterative processes similar to the student's third phase reflection sketches, albeit more layered and nuanced.

Figure 1 is a model of how design expertise might change over time, tracking a designer from Dreyfus' naïve to expert stages. The naïve designer understands little about the design process. Terms, if any, are abstractions and linearly arranged. As the student gains experience with team-based authentic design challenges, the student's representation of the design process becomes increasingly complex; as new methods are introduced and practiced, the method is integrated into the first design process drawings. The once naïve drawings take on a more iterative and detailed view of design. However, as the student gains more experience and moves into the world of practice, the methods become nuanced abstractions in the practitioner's mind; the various "design moves" that have been learned and embedded in the individual designer's philosophy and identity become contextually based, less rule-driven, and increasingly tacit. This ultimately leads to a return to a more business-driven, linear and simple abstraction, but unlike the naïve student, this abstraction is filled with nuanced and layered understanding. For the practitioner, a mere squiggle as in the top-half of Figures P1 or P5, represents a great deal of meaning.

Limitations and Implications for Future Research

We present an exploratory analysis of visual reflection, which must be contextualized within the specific pedagogical environment in which the students and practitioners represented in this study are trained. Due to the highly situated nature of this educational experience, generalizations to other HCI programs, design programs at large, or even future cohorts within this same program are discouraged. While the sketches reproduced and analyzed in this manuscript represent a wide cross-section of incoming ability, educational and professional experience,

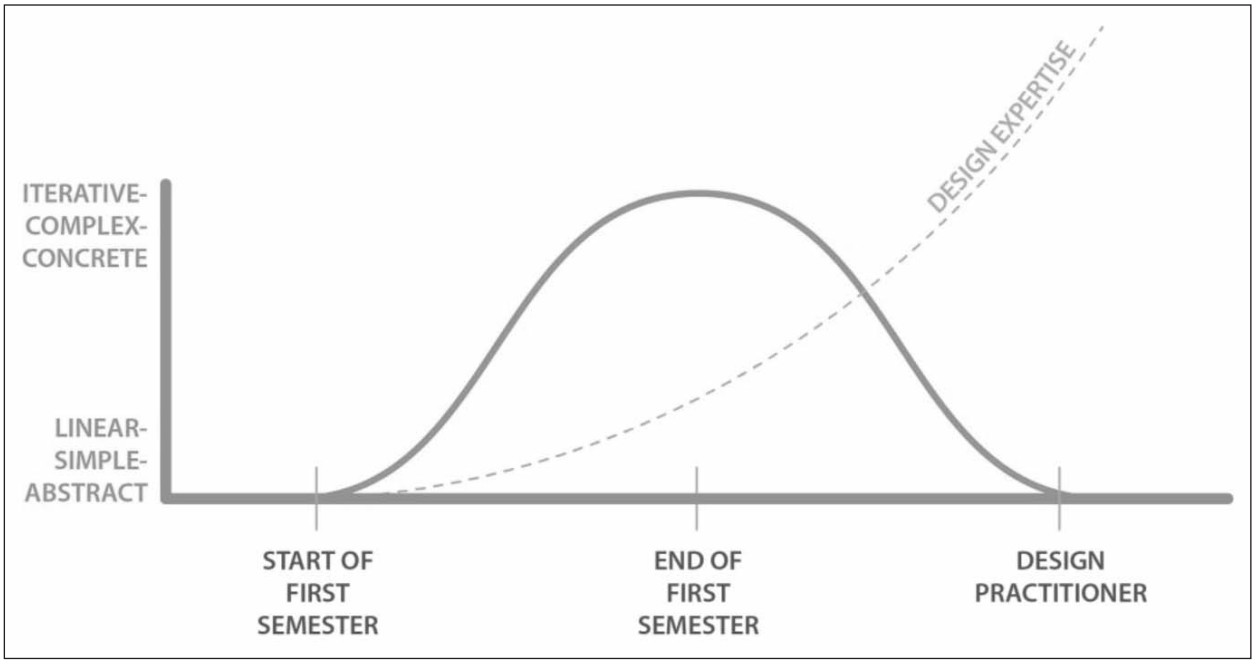

Figure 1. Complexity of reflection compared with the development of design expertise over time

gender, and country of origin, the relatively small scale and selection criteria must be considered when viewing and synthesizing the corpus of reflection sketches. Future work drawing on students from multiple programs within a single design discipline, or within the framing of a more interdisciplinary or transdisciplinary view of design might result in a more comprehensive view of the efficacy of sketching the "whole game" as an act of reflection in relation to the development of design thinking.
Despite the limitations of the method employed in this study, it also opens a number of possible directions for future research, including further development of a design pedagogy, understanding of design expertise, thresholds between student and practitioner thinking, and the dynamics of design thinking in professional practice.

For instructors of design, encouraging students to draw a picture of their process understanding has two pedagogical goals: 1) the act of drawing solidifies the student's understanding of the design process, and 2) the resultant artifact becomes an object of discussion for instructor-student dialogue about the process. The act of sketching, like all design sketches, invites conversation and debate, forming a shared artifact that could constitute a form of distributed cognition (Hollan, Hutchins, and Kirsh, 2000). Whether the engagement is for improved learning or for a critical review of an existing process, the whole game sketch provides value at multiple points along the naïve- expert design continuum. Future investigation into the efficacy of sketching as a way of representing design thinking could help to formalize visual reflection and the resulting dialogue in a more holistic way. This tool may also be helpful to judge the effect of other interventions within the curricular system; for instance, how students are connecting new concepts or methods being utilized in the classroom environment.

Additional work on design expertise, building on the work of Dreyfus (2003), Lawson and Dorst (2008), and Nelson and Stolterman (2012) is also an important area of opportunity for future research. As noted in Figure 1, tracking expertise over time is difficult due to the increasingly tacit nature of design knowledge. Further expansion of the work shown in this preliminary schema could expand knowledge of critical thresholds, including the transition from academia to practice.

When looking more closely at design practice, it is important to note that the practitioners in this study often initially resisted drawing the "whole game." Yet, when they did so, they found it to be an artifact worthy of discussion and reflection – and potentially a re-examination of their company's process. In this respect, sketching as a way of reflecting may be helpful as a tool to make design processes more explicit and tractable in a business context. When investigating the patterns of thinking of design practitioners, it is important to investigate their tacit assumptions and business translation of design concepts. This remapping seems to occur seamlessly over time, so it is difficult to track evolution of changes without artifacts of explicit reflection.

The comparisons between design students and practitioners also surface a number of issues related to design expertise, articulation of design thinking, and recognition of factors that affect an individual's design process. These factors could forge additional connections between research and practice – including our knowledge of how practitioners work, what things they care about in their process, and how this knowledge may inform future design pedagogy. Any attempts to inform changes to the pedagogy directly from these findings would be premature, but future work in understanding how design students and practitioners think about and articulate their conceptions of design could strengthen the connection between pedagogy and practice in a more generative way. In particular, the underlying structures of teamwork and business language that dominated the sketches of practitioners could represent a terminal goal for design education to progress toward, even if these skills are not directly taught as part of the formal design program, and further work into these connections could provide additional insights on changing the formal and informal pedagogy, working toward changing both surface features and epistemological features of the studio (Shaffer, 2003).

Conclusion

In this study we asked two different groups – naïve interaction design students and expert interaction design practitioners – to respond to the prompt "draw a picture of 'playing the whole game' of HCI Design – the real game." For the students, we analyzed at their drawings across three different time points during their first semester of design education. The practitioners made a single drawing in the context of a larger interview about design processes and use of design methods. Our analysis of both sets of sketches shows that naïve designers move from a limited, largely linear, and abstract notion of the design process to

a more richly detailed, concrete, and iterative understanding of design. In contrast, the practitioners created sketches that reflected their integrated and tacit understanding of design practice in a situated business setting, including an awareness of multiple players contributing to the success of a given design project.

For design students, drawing the whole game of HCI design allows them to make explicit their understanding of the design process as a schema, and, in particular, reflect as their understanding of design changes over time. For the practitioners, drawing the whole game allows them to reflect on a process that has become internalized and situated in a particular context of practice. For the researchers, the drawings represented longitudinal artifacts, reflecting an imprecise yet non-trivial indicator of learning. These drawings varied across time from naïve to expert views. The student drawings show what was learned over a one-semester engagement with a series of team-based design challenges, while the practitioner drawings show a business-driven and integrated view of a situated design process.

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