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CHARACTERIZING COMPETENCIES FOR HUMAN-CENTERED DESIGN

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ABSTRACT

Employees and employers alike increasingly value human-centered design, as it can drive innovation across a wide range of industries. With the growing interest in understanding human-centered design processes as they apply in different professions, there is a rising need to recognize the specific competencies necessary to perform these jobs well. Though there is a body of research on how people discover, create, and use design methods, there is a lack of understanding on what core competencies are necessary for people to apply these methods. Previous interactions with target users of *theDesignExchange,* an interactive community-driven portal to support design researchers and practitioners, have demonstrated a desire for increased awareness of the competencies required for employability and for successful design practice. This paper reports on a portion of an expansive competency-finding project aimed at identifying the core set of competencies that human-centered design practitioners need and employers seek.

In this paper, we present our lists of cultivated mindsets, specialized disciplinary skills, contextualized tasks, and basic skills in human-centered design. These lists represent a first pass at identifying the essential and underlying competencies a practicing or aspiring human-centered designer must have in order to perform their current or future design tasks. The work we present in this paper serves as a preliminary starting point for future research interviews with design practitioners and employers, as we seek to understand human-centered design competencies.

INTRODUCTION

Human-centered design and design thinking are approaches to developing a deep understanding of potential users or other stakeholders to drive design ideation and decision-making processes. Illustrating the connection between human-centered design [1] and design thinking [2], Tim Brown, president and CEO of IDEO, states on his company's webpage: "Design thinking is a human-centered approach to innovation that draws from the designer's toolkit to integrate the needs of people, the possibilities of technology, and the requirements for business success" [3]. Brown and IDEO used their conceptualization of design thinking to popularize human-centered design by linking its principles to the needs of the business world [1]. Though the popular concept of *design thinking* has mainly been applied within the realm of product development, the roots of the term can be traced back to Peter Rowe's 1987 book "Design Thinking" [2]. In the book, Rowe credits Rittel and Webber's (1973) [4] presentation of *wicked problems* – problems that require iterative processes that can only be understood within socially complex contexts – as inspiring the tenets of design thinking [4].

As the practice of human-centered design – including design thinking – has become more popular, practitioners from many different backgrounds have begun to incorporate human-centered design principles in their work. Despite its growing multi-disciplinarity, human-centered design's core set of underlying competencies remains poorly understood. Throughout this paper, we use the term "competencies" broadly to encompass a range of mindsets, skills, and tasks. The wide range of human-centered designers, including those in engineering, design, architecture, business, public policy, education, and more, each have their own unique set of mindsets, tasks, and skills. In this work, we begin to characterize the fundamental competencies in human-centered design that transcend the practitioner's discipline. The preliminary sets of competencies that we present in this paper are hypotheses; in our future work, we will validate the competencies with practitioners of human-centered design and their employers.

BACKGROUND

The Importance Of Design In Employment

Human-centered design (HCD) is becoming more and more prevalent in industry and in employment. In 1997, a Product Development and Management Association (PDMA) study found that new products accounted for almost one-third of the revenues from a sample of US-based companies [5]. PDMA also found that those companies who followed a formal

design process, engaging with users and undertaking extensive design research, were the highest performing.

In 2007, the UK Design Council performed in-depth qualitative research with eleven of the world's leading companies [6]. The Design Council found that these companies all invest in design and follow a structured design management process. In another study, the UK Design Council engaged in a large survey and interview research project, seeking to understand what UK businesses perceive as the "value of design" [7]. They found that half of the businesses surveyed believe that design had given them a competitive advantage in the course of the previous ten years. Those businesses that consider design to be integral generally enjoy higher profits, higher share prices, and more rapid growth. More recently, the Design Management Institute (DMI) did a similar study examining the stock performance of design-led organizations, where they found these organizations outperformed the S&P by 219% over the ten-year period from 2004 to 2014 [8].

These studies suggest that design plays an integral role in corporate success, and employers increasingly value employees who can apply HCD approaches in particular. It is important to note that the studies performed by PDMA, the UK Design Council, and DMI are potentially skewed, given that these entities may be biased to see an overly positive view of design in industry. However, a review of current news on the subject shows that many companies, including Capital One [9] (D. Lemus, personal communication, July, 24, 2015), General Electric [10], Proctor & Gamble [10], IBM [11], [12], and Ford [13], are currently in the process of building out their internal HCD capabilities, going so far as to train even non-design personnel in the HCD process. This training is meant both to arm the employees with new problem-solving abilities and to create a culture of innovation. The Harvard Business Review recently called out this shift in a special issue on Design Thinking [14]–[17], reinforcing what appears to be a trend towards developing HCD capacities in large organizations. As more companies follow this path, it becomes imperative to recognize and prioritize the competencies necessary in HCD.

Understanding Design Competencies

Many studies have sought to understand the competencies necessary in specific design fields. In Wilde's discussion of the competencies necessary in successful engineering design [18], he argued that design is often undervalued, contributing to the (then) pervasive lack of engineering designers working in industry. Wilde went on to point out "the designer's specialty is multi-disciplined synthesis applied to a purpose," therefore stressing the importance of inter-disciplinary education and opportunities to apply educational theories in practice.

Cross, Christiaans, and Dorst explored the differences in competencies between novice and intermediate undergraduate design students [19]. They expected to find a predictable development of design skills throughout students' design education but instead found that design skill development was highly variable and not necessarily attributable to a student's education level. Cross et al. did, however, show that design abilities could be taught. Therefore, they pointed to the need for more deliberate educational programs to develop students' design competencies.

Lewis and Bonollo investigated the competencies of successful industrial design students [20]. In their empirical study, they evaluated five dimensions of design process competencies: (1) task clarification; (2) concept generation; (3) evaluation and refinement; (4) detailed design; and (5) communication of results. In their evaluation, they also discovered more general competencies that mark "professional behavior": (1) negotiation with clients; (2) problem solving; (3) acceptance of responsibility for outcomes; (4) interpersonal skills; and (5) project management.

Dym, Agogino, Eris, Frey, and Leifer [21] explored design thinking in the context of engineering education. They defined engineering design as "a systematic, intelligent process in which designers generate, evaluate, and specify concepts for devices, systems, or processes whose form and function achieve clients' objectives or users' needs while satisfying a specified set of constraints." From this definition, they highlighted several competencies associated with design thinking in engineering: (1) divergent-convergent questioning; (2) thinking about designing systems; (3) making design decisions; (4) design thinking in a team environment; and (5) the languages of engineering design (including verbal, graphical, and mathematical languages). Dym et al. then explored project-based learning as a design pedagogy in engineering education. They discussed how project-based learning appears to improve student learning, but more work needs to be done to integrate design thinking into engineering curricula.

D'Souza, Yoon, and Islam utilized a virtual reality environment to explore the design skills of Generation Y (a.k.a., Millennials) [22]. They applied Howard Gardner's theory of multiple intelligences [23] as a framework to study the architectural design skills of the 11 to 16 year old designers. Figure 1 shows the eight multiple intelligences proposed by Gardner.

Intelligence type	*Description*
Linguistic/verbal	Use words in creative ways
Musical/rhythmic	Appreciate/perform sounds
Logical/mathematical	Think in abstract relations
Spatial/visual	Manipulate/transform spatial information
Bodily-kinesthetic	Use body to solve problems
Intrapersonal	Responsive to personal feelings
Interpersonal	Responsive to feelings of others
Naturalistic	Appreciate/manipulate nature

Figure 1. Multiple intelligence types, proposed by Gardner [23], presented by D'Souza et al. [22]

D'Souza et al. articulated the specific architectural design competencies that correspond to Gardner's multiple intelligence type categories and they then tested how well the young designers met each of these competencies.

These works, and many others, identify competencies by observing or collecting other qualitative data on designers *as individuals*. There are clear benefits in seeking to understand competencies by engaging in research with the competency-holders themselves. However, there are also clear benefits in seeking to understand competencies from a more abstract level. In this study, we aim to understand the competencies necessary in human-centered design by looking at the methods an HCD practitioner might use in their work. No study to our knowledge has sought to understand design competencies through a method or task analysis. Our study fills this gap.

Moreover, when we undertook an initial exploration of HCD job descriptions (e.g., job descriptions for design researchers, UX researchers, etc.), we found that employers tend to list the methods and tasks they expect potential employees to undertake, rather than the competencies they expect potential employees to hold. This underscored our decision to pursue a method-based competency analysis.

Understanding Design Methods - *theDesignExchange*

The notion of a "design method" was first proposed at the *Conference on Systematic and Intuitive Methods in Engineering, Industrial Design, Architecture, and Communications* in 1962. Conference participants discussed the necessity for designers to engage in multi-disciplinary efforts, where they can contribute their unique skills and disciplinary experience to any sort of project [24]. A design method is a rational procedure that prescribes a specific way to proceed in a design task, and it is generally applicable to more than one type of problem [25].

TheDesignExchange (available at thedesignexchange.org) is an online portal that currently provides the most comprehensive online repository of design methods with over 300 unique design methods, collected from academic publications, online collections, books, and industry toolkits. Although it is based on a large set of methods available in the literature, *theDesignExchange* is not intended to be complete, as the goal is to have the design practitioner community contribute and add to the corpus of methods. *TheDesignExchange* does, however, provide the largest set of design methods available on the web to date and thus provides the largest database available for our research.

Each method on *theDesignExchange* is tagged with a set of defining characteristics, forming the basis of an ontology for categorizing design methods. More detail on this ontology can be found in our previous work [26]. Each method is also given a brief description and linked to a process description. Figure 2 below shows an example method description and tagging structure for "storyboarding."

Description	"***Storyboards***, derived from the cinematographic tradition, represent how a design concept may be used by a customer through a series of drawings or pictures put together in a narrative sequence. It shows every touchpoint the customer may have with the design during the experience."		
Stage of process	Mockup	**Prototyping format**	Abstract
Fidelity	Low	**Aspect**	Role or context
Offering format	Either	**Scope**	Horizontal
Product or service	Either	**Purpose**	Experiment, Explore, Persuade

Figure 2. Method description and ontology tags for *storyboarding* [26]

The process description for our example method, storyboarding, comes from Gamestorming.com [27], a site that has a collection of (mostly ideation) methods appropriate specifically for groups:

> *Storyboarding:* Before the meeting, determine the topic around which the players will craft their "ideal" story. Once the meeting starts, divide the group into pairs or groups of three or four, depending on the size of the group. Provide markers, pads of flip-chart paper, and stands.
>
> 1. Tell the players that the purpose of this game is to tell the other players a feel-good story. The topic of the story is "The Ideal Future for [blank]"—for a team, a product, the company, whatever you decided beforehand. The players' assignment is to visually describe the topic and narrate it to the group.
> 2. After the groups are established, give them 20–25 minutes to (1) agree on an ideal state, (2) determine what steps they would take to get there, and (3) draw each step as a sequence of large images or scenes, one per sheet of flip-chart paper.
> 3. Give the players a two-minute time warning, and once the time is up, bring them back together. Ask for volunteers to tell the story first.
> 4. After all the groups have presented, ask them what's inspiring in what they heard. Summarize any recurring themes and ask for observations, insights, and "aha's" about the stories.

The collection of HCD design methods, descriptions, and processes found on *theDesignExchange* forms the basis of the method analysis underlying our competency discovery process. We assume that because methods are specific actions and tasks that a designer undertakes in their design process, there are specific competencies associated with accomplishing these tasks. Stated another way, we believe that we are able to extract competencies from methods by understanding the particular steps a designer takes when implementing a method. We do not assume that our process results in an entirely complete or validated set of competencies, but we do posit that our choice to extract competencies from methods results in a valuable contribution that can form the basis for further investigation and validation with product managers and practicing HCD designers.

METHODOLOGY

Our compilation of competencies was born from a detailed examination of each individual design method found on *theDesignExchange*. Using an inductive research approach, a team of three researchers (Researchers A, B, and C) used a description of each method's detailed process to identify the tasks required to implement each method. They then performed a qualitative content analysis [28], where they used their judgment to independently extract the competencies necessary to conduct the required tasks. The researchers built on prior

literature in design methods and design thinking skills, but did not look for predefined competencies in their content analysis; they sought to uncover the full scope of competencies present in the method set. The researchers paired off (Researchers A & B and Researchers A & C), and each pair of researchers discussed and reconciled the identified competencies for each particular method. As all researchers worked together to achieve consensus, a quantitative inter-coder reliability check was not needed [29]. After all methods were examined, the identified competencies were compiled into a draft list, giving an initial set of 110 unique competencies.

The researchers worked with a broad definition of "competencies," expecting most if not all of what was necessary for each method to be a clear fundamental skill. As they examined the collection of 110 competencies, however, they realized that there were some key differences between, for example, a way of thinking (e.g., divergent thinking) and the ability to perform a task (e.g., drawing). Therefore, Researcher A performed an open card sorting activity (a method often used in usability research [30], applicable in design research as well [31]), grouping competencies by "competency type." During this sorting process, Researcher A found four unique categories of competencies. The resulting categories from the card sort activity are presented in the Findings section.

Researcher A continued to iterate on the competency categories, clarifying the wording and re-assessing whether or not each competency was unique unto itself. At the end of this highly iterative process, there were 101 unique design competencies across four HCD design competency categories. The activities of the research methodology are presented in Figure 3.

In the Findings section, we present our list of competencies and their associated descriptions. We also present and explain each of the competency categories.

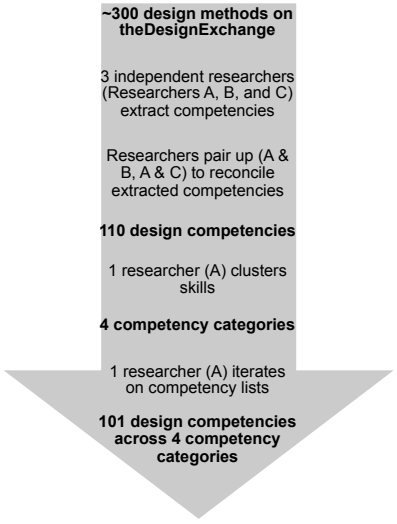

Figure 3. Methodology of extracting, categorizing, and iterating on HCD design competency lists

FINDINGS

The open clustering of HCD competencies resulted in the following specific categories: *cultivated mindsets, specialized disciplinary skills, contextualized tasks,* and *basic skills.* The subsections below contain specific definitions of each category of competencies. Each of these categories of competencies represents different areas of interest that an employer may consider when hiring an HCD practitioner.

An employer may seek to understand a job applicant's core *cultivated mindsets* and ability to adopt alternative mindsets in order to understand whether or not the applicant would be a good fit for the job. An employer may assess an applicant's relevant background or *specialized skills* when considering whether or not the applicant is qualified for the job at hand. An employer may need to know if an applicant is able to perform the specific *contextualized tasks* that occur in the job's typical course. An employer may evaluate job applicants based on the *basic skills* they can offer to the company by having them perform particular tasks or evaluating their past work (e.g., in a portfolio).

Cultivated Mindsets

A mindset in the simplest terms is a way of thinking. A person's core mindsets can be formed and altered, but they represent a person's underlying values and ways of being. A person can shift their core mindsets over time through focused practice, or they can temporarily adopt a particular mindset though either priming or intention. We define a cultivated mindset as a set of accepted norms, understandings, and paradigms that a person adopts, either as a part of their core mindset or as a temporary mentality dependent on context.

Table 1 shows our list of cultivated mindsets for HCD.

Table 1. Cultivated mindsets for human-centered design

Mindset	Description
Abstract thinking	The inclination to identify shared attributes between objects or facts and generalize to a larger pattern or goal
Adaptivity	The practice of adjusting and modifying to changing environments and conditions
Analogical mapping	The habit of taking inspiration from seemingly unrelated concepts and apply them to the context at hand
Business savvy	The acute perception of the business workings of a situation
Collaborative mentality	The practice of regularly communicating and sharing responsibilities with others and building off their work in order to achieve a shared goal
Concrete thinking	The inclination to focus on details and attributes associated with execution or usage without generalizing
Convergent thinking	The tendency to bring in many sources of information in order to arrive at a consensus and to proceed forward with a decision
Creativity	The consistent ability to find, create, and build new things
Curiosity	The desire to explore, investigate, and remain inquisitive
Detailed thinking	The inclination to explore and express the small and fundamental details of an idea
Divergent thinking	The tendency to constantly seek new information, to maintain a spontaneous and free-flowing mentality
Empathy	The capacity and the practice to understand others' thoughts, feelings, and experiences

Futures thinking	The practice of systematically thinking through all possible cases that may occur in the future
Holistic thinking	The regular tendency to think of and maintain a vision of the "big picture"
Humility	The tendency to maintain a modest view of one's own importance or capability
Initiative	The inclination to know when action is needed and to take such action
Leadership	The inclination to successfully organize a group of individuals into a productive team
Open-mindedness	The willingness to consider others' ideas and feedback
Organization	The habit of arranging and keeping track of ideas and objects in a logical and accessible manner
Quick thinking	The tendency to act on intuition and "gut" feelings or reactions
Self-awareness	The maintenance of one's own awareness of their thought processes, biases, and insights
Social savvy	The acute perception of social situations, allowing one to communicate with the audience in an exciting and accessible way
Spatial awareness	The inclination to recognize and contextualize elements, usually of an idea, prototype, or design, in space in relation to one another
Tenacity	The quality of being able to persist and maintain determination in the face of obstacles
Unbiased thinking	The habit to consciously minimize the influence of preconceived notions
Visual thinking	The inclination to recognize, understand, and analyze the visual layout and aesthetics of objects, whether 2D or 3D
Willingness to fail	The established habit of suspending the need for success and holding the fearlessness of fail failure

Specialized Disciplinary Skills

We define a specialized disciplinary skill as one that requires formal education or extensive experience, generally representing a specialty or sub-discipline. Table 2 shows our list of specialized disciplinary skills for HCD.

Table 2. Specialized disciplinary skills for human-centered design

Specialized trade skill	Description
Accounting	The practice of preparing and examining accurate financial records
Acting	The technique of using words and gestures to tell a story and evoke a reaction from an audience
CAD	The use of computer technology to create representations of physical objects or designs
Data analytics	The ability to use mathematical and statistical techniques to explore, interpret, and analyze a set of quantitative data
Engineering analysis	The ability to analyze the technical engineering details of a problem, an idea, or a potential solution
Filmmaking	The ability to stage, shoot, edit, and produce a film in order to share a story
Graphic design	The ability to commit ideas and designs to paper or file via photography, Photoshop, Illustrator, and similar tools
Laser-cutting	The ability to design for and operate with a laser-cutting machine
Manufacturing process design	The ability to understand, conceive of, and create a process for manufacturing a product
Photography	The ability to capture photographs of meaningful situations or people, therefore sharing through visual communication
Project management	The ability to guide a team to initiate, plan, and execute a design challenge

Basic Skills

We define a basic skill as an underlying essential ability common in HCD. Table 3 shows our list of basic skills for HCD.

Table 3. Basic skills for human-centered design

Basic skill	Description
Abductive reasoning	The ability to draw the best possible explanation from a set of observations
Active listening	The ability to listen by fully engaging and using all senses to listen and respond in a conversation
Clarifying	The ability and habit of asking pointed questions and re-stating what has been already heard in order to confirm understanding
Critiquing	The ability to give balanced and useful feedback on others' work in order to promote improvement
Decision making	The ability to employ a systematic and unbiased process to first understand the potential choices and then to choose which choice is best for the given context
Deductive reasoning	The ability to draw a specific and guaranteed conclusion from a set of premises, which are assumed to be true
Defining the problem	The ability to clearly define and recognize the boundaries of the problem being addressed
Delegation	The ability to assign and distribute tasks in a project to others in order to maximize effectiveness and efficiency
Digging deep	The ability to push beyond the obvious and therefore uncover core insights
Drawing	The ability to commit ideas and designs to paper or file by drawing them out, ideally with strong fundamentals in perspective, proportions, and so on
Explaining in simple terms	The ability to break down a complex topic and explain it to the average person on the street, in a company, or someone without a high-level understanding of the field
Facilitating	The ability to facilitate a conversation between multiple parties and guide the conversation so as to keep it on task and topic
Goal setting	The ability to clearly articulate specific and realistic aims for what is to be achieved in a process or project
Identifying core components	The ability to uncover the central aspects or subcomponents of a problem or concept
Identifying key insights	The ability to pull out the most useful revelations from research
Identifying known and unknown	The ability to objectively analyze what is currently known and not known about a specific issue or situation
Identifying obstacles	The ability to foresee and address potential problems that might impede project progress
Identifying patterns	The ability to recognize clusters or commonalities in data or ideas, and extrapolate these commonalities more broadly
Improvising	The ability to react quickly and without other information to a scenario with whatever is available on hand
Inductive reasoning	The ability to take a specific observation and apply it in a more general context, drawing a likely but not guaranteed conclusion
Mentoring	The ability to support others in growing and learning by providing guidance and advice
Observing	The ability to pay attention and notice insights from a set of actions
Pivoting	The ability to continually try out new ideas and move in new directions based on an understanding of present and future trends
Persuading	The ability to coax someone towards a certain desired outcome or decision
Prioritizing	The ability to create and manage a list of tasks, in order of their priority level

Record-keeping	The ability to create and maintain thorough documentation and records of all thoughts, communications, or iterations, among others
Reframing	The ability to consider a problem or situation from multiple unique perspectives
Representing ideas visually	The ability to transcribe and represent ideas in physical form that is not limited to drawing
Story building	The ability to build a compelling story and set of characters to represent the problem or idea at hand
Story telling	The ability to tell a story about the problem or idea at hand that engages and motivates the audience
Synthesizing information	The ability to take all the information that was gathered from observation and/or listening and formulating coherent ideas, conclusions, and inferences from that information
Trust building	The ability to create a supportive environment by communicating openly and honestly with team members
Understanding tradeoffs	The ability to know how consequences are tied together and how manipulating a circumstance will result in other outcomes
Working under time pressure	The ability to produce the desired results of ideation in short time frames that could range from weeks to hours

Contextualized Tasks

We define a contextualized task as an activity that is necessitated by specific circumstances. These are tasks that require a certain skill level to accomplish well, but may draw on multiple skills to complete.

Table 4 shows our list of contextualized tasks in HCD.

Table 4. Contextualized tasks for human-centered design

Contextual task	Description
Analyzing strengths and weaknesses	Objectively analyze a current or future situation or idea for its strengths and weaknesses
Assessing viability	Determine if a design has or will have to capacity to be feasible or sustained
Canonical research	Conduct a comprehensive review of research contained within a project's body of governing rules, principles, and standards
Creative use of materials	Use available materials in a novel or non-conventional way to represent an idea or design
Data abstraction	Take concrete data or observations and transform it into more abstract insights or patterns
Idea presentation	Present and explain an idea or design so that others are able to understand it and provide feedback
Ideating under constraints	Create ideas under specific constraints laid down by the problem or other practical limitations
Identifying markets	Find new or underserved markets to direct efforts toward
Interviewing	Ask thoughtful questions and engage in meaningful conversations in order to understand people's habits, behaviors, beliefs, and other relevant information
Layout	Organize information and interactive elements in a pleasing and useful way
Making group decisions	Lead a working group towards a mutual agreement
Navigating online communities	Follow leads and links on the internet to discover relevant information
Need finding	Discover people's needs—both those they say they have, and those they might not even realize.
Noticing what's improvable	Identify which elements of the current design have the most room for improvement so as to focus on those when ideating
Qualitative data collection	Collect qualitative data useful in further research or analysis
Quantitative data collection	Collect numerical or quantitative data useful in further research or analysis
Recruiting and following up with people	Find and keep in touch with a set of people necessary in the design process
Report writing	Compile a summary that communicates relevant design activities to stakeholders
Resource allocation	Redirect and allocate limited time and resources in the most effective manner
Seeking alternative perspectives	Intentionally look for diverse perspectives to provide feedback on a design or idea
Selling	Find the appropriate outlet for a given design and to persuade a stakeholder to buy into the design
Stakeholder identification	Identify which individuals and groups (the design team, users, the client, etc.) are most essential to the project at hand and ideate accordingly
Survey design	Create an unbiased, comprehensive, and understandable survey tool
Synthesizing multiple ideas	Take multiple ideas from different sources and synthesize them using the best elements of each original idea
Touchpoint identification	Identify all parts of the product or service that the user interacts with or that interact with each other
Understanding historical trends	Understand the trends that occur over a period of time
Use case identification	Recognize the product or service in many varied potential use scenarios
Visualizing data	Translate raw data into understandable images
Writing for the public	Write summaries and communicate meaningfully with external parties

As stated earlier, a contextualized task is actually a composite of multiple skills. For example, to perform the contextualized task of *recruiting and following up with people*, one must hold particular mindsets (e.g., *initiative* and *tenacity*) and skills (e.g., *trust building*). Therefore, we broke down the contextual tasks into their necessary skills. For each task, we analyzed our lists of basic skills, specialized disciplinary skills, and cultivated mindsets and determined which of these are necessary for the contextual task. A sample of these necessary skills is provided below in Table 5. The full list of necessary skills for contextual tasks is provided in Annex A.

Table 5. Sample of skills necessary in contextualized tasks

Contextual task	*Necessary basic skills*	*Necessary specialized disciplinary skills*	*Necessary cultivated mindsets*
Assessing viability	Determine if the idea going forward will be viable commercially and feasible to make or implement		
	Abductive reasoning	Accounting	Business savvy
	Analyzing strengths and weaknesses	Engineering analysis	Convergent thinking
	Defining the problem		Detailed thinking
	Identifying known and unknown		Futures thinking
	Identifying obstacles		Holistic thinking
	Reframing		Organization
	Understanding tradeoffs		Willingness to fail

DISCUSSION

Comparison to Prior Studies

In Wilde's discussion of the competencies needed for successful engineering design [18], he illustrated the importance of a multidisciplinary design practice, which is well supported in our own findings. Our work extends his discussion by formally assembling these competencies into a list. The competencies that we found are crosscutting and prevalent across specific disciplines. Furthermore, as we discuss below, the sheer volume of competencies suggests that a single designer cannot expect to be competent in all aspects of design; the designer must depend on a diverse team to complement competencies.

The competencies of novice and intermediate undergraduate design students, explored by Cross, Christiaans, and Dorst [19], aligned closely to the competencies we discovered in our work:

"(i) The production of novel, unexpected solution concepts" corresponds to *Creativity* (cultivated mindset) and *Ideating under constraints* (contextualized task), as presented in our competency lists.

"(ii) The ability to tolerate uncertainty, working with incomplete information" corresponds to *Adaptivity* (cultivated mindset) and *Identifying knowns and unknowns* (basic skill), as presented in our competency lists.

"(iii) The use of imagination and constructive thought" corresponds to *Creativity* (cultivated mindset) and *Critiquing* (basic skill), as presented in our competency lists.

"(iv) The use of drawings and other modeling media as means of problem-solving" corresponds to *Visual thinking* (cultivated mindset), *Layout* (contextualized task), *Visualizing data* (contextualized task), and *Drawing* (basic skill), as presented in our competency lists.

The Cross et al. study was not extractive, as the authors intentionally chose to focus on these aspects of design expertise. Our findings extend the work of Cross et al. by extracting more aspects of design expertise.

Lewis and Bonollo [20] began by evaluating five design process skills: (1) task clarification; (2) concept generation; (3) evaluation and refinement; (4) detailed design; and (5) communication of results. These skills are fairly high level, and our lists of competencies complement Lewis and Bonollo's work by providing more specific skills that address the same themes.

Lewis and Bonollo also found five dimensions of "professional behavior" in design: (1) negotiation with clients; (2) problem solving; (3) acceptance of responsibility for outcomes; (4) interpersonal skills; and (5) project management [20]. The competencies we identified are not explicitly linked to "professional behavior," and though we found aspects of some of these dimensions (e.g., *Empathy*, a cultivated mindset, is an aspect of interpersonal skills), they are not fully represented within the competencies we found. This makes sense, because the different dimensions of "professional behavior" that are required in different contexts cannot be thoroughly addressed by simple method process descriptions. This suggests that a more nuanced examination of the contextual applications of design methods may reveal further specific competencies within these areas as well. That being said, however, we still see overlap between our lists of competencies and the dimensions of behavior that Lewis and Bonollo identify, particularly in the problem solving and project management dimensions, which suggests that our approach is a valid complement to their approach.

Dym, Agogino, Eris, Frey, and Leifer [21] addressed the teaching of design thinking skills with a focus on project-based learning. They highlighted competencies associated with: (1) divergent-convergent questioning, (2) systems thinking, (3) decision making, (4) teamwork, and (5) communicating with the different languages of design (e.g, sketches, prototypes, and stories). These competencies are addressed in our lists of competencies for human-centered design, except for some of those listed under systems thinking. We clustered the ability to think about system dynamics and to conduct experiments into our set of specialized disciplinary skills associated with technical analysis. We note that we did identify competencies associated with data analysis: *Data analytics* and *Engineering analysis* address the ability to use mathematical and statistical techniques to explore, interpret, and analyze a set of quantitative data.

D'Souza, Yoon, and Islam explored architectural design skills of children [22]. The specific architectural design skills they explored were articulated in the Architecture Design Intelligence Assessment Scales (ADIAS), a survey instrument that D'Souza et al. used to link skills to intelligence types. The skills in ADIAS, and the intelligences in Gardner's framework (linguistic/verbal, musical/rhythmic, logical/mathematical, spatial/visual, bodily-kinesthetic, intrapersonal, interpersonal, and naturalistic) [23], are encompassed within the set of competencies that we have extracted. While we have not made an effort to link competencies to intelligence types, we do see that each of the eight intelligence types can be mapped to specific competencies that we have extracted.

The lists of competencies we have provided in this paper contribute to the broader conversation of design competencies. The similarities that we have noted in our findings and the findings of previous studies illustrate the benefits of a method-based extraction approach. Furthermore, our competency analysis extends and complements the set of competencies that have been considered in previous work. The competencies that we found are not exhaustive, as demonstrated by the competencies discussed in previous studies that were not found in ours. However, we do add a large set of competencies that have not previously been explored to the body of design skills research.

Skills Unique to Human-Centered Design

In this work, we did not attempt to find competencies unique to only HCD. Rather, we were interested in exploring the tasks of HCD in order to discover and classify the requisite competencies. An interesting area of future work may be to compare these lists to the competency lists of other disciplines.

We also did not prioritize these competencies as to their relative importance for HCD. As mentioned in the Background and Introduction, HCD approaches are generally multi-disciplinary and therefore designers are able to complement their skillsets with those of their teammates. We do not claim that a human-centered designer must have all of the competencies identified; rather, we suggest that the competencies housed in the lists above are those that commonly underlie HCD design processes. In the future, we will explore how often these competencies manifest in practice.

Implications for Human-Centered Design Practice

Our competency-finding project suggests several implications for the continued practice of HCD. While most of the competencies fell into non-disciplinary-specific categories (cultivated mindsets, contextualized tasks, and basic skills), several fell into the disciplinary-specific category of specialized disciplinary skills. The skills housed in this category are each born of their own particular field (e.g., accounting, filmmaking, photography). The fact that all of these various disciplines appear in the process for multiple design methods implies a multi-disciplinary design approach. It suggests that HCD not only benefits from but requires collaboration between designers and team members across a range of disciplinary backgrounds. This insight is not new, but it does underscore the importance of working within a diverse team, even when the team members themselves may have a diverse skillset.

No single designer can hold expertise in all of the competencies found in this work; rather, designers must form teams to complement the competencies that each team member already has and the competencies each team member hopes to acquire. An individual human-centered designer does not need to be an expert in each design process phase, but should hold some expertise in a set of competencies that contributes to the team. Teams should seek to amplify the individual sets of competencies and to create a comprehensive portfolio of competencies across the phases of the design process. This has particular implications for those seeking to enter into the practice of HCD, as they can choose to focus their efforts on strategic competency depths rather than competency breadth.

CONCLUSIONS AND FUTURE WORK

We engaged in an expansive competency-finding project by analyzing the competencies necessary in design methods specific to human-centered design. In this process, we identified four categories of competencies: *cultivated mindsets, specialized disciplinary skills, contextualized tasks,* and *basic skills.* Each of these categories housed a number of unique design competencies, ranging from "tenacity" (cultivated mindset) to "persuading" (basic skill). We provided descriptions of each of these competencies.

While we do not consider the impacts of competency assessment in our work, we recognize that employers must be able to recognize the competencies that potential employees do and do not have. Similarly, aspiring and practicing human-centered designers must be able to understand their own competency levels.

Any potential employer will have unique resource constraints, and will therefore prioritize the "quality" of their competency assessment differently. Some employers may choose to rely only on an in-person job interview, assessing skills and mindsets through the interviewee's stories and responses, while others may ask their potential employees to submit a full portfolio or to complete a technical challenge to show evidence of particular skills and competencies.

In our future work, we will seek to understand the challenges that employers face in assessing the competencies of their potential hires. We will also consider innovative ways to assess design skills in the context of both self-assessment and hiring assessment.

In future work, we will also explore whether these categories of competencies necessary in HCD work are also the skills that hiring managers value when they seek new design employees. Our insights into design skills will also be provided on *theDesignExchange* in order to more broadly disseminate our findings to the HCD community.

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ANNEX A

COMPETENCIES NECESSARY IN CONTEXTUALIZED TASKS

Contextual task	*Necessary basic skills*	*Necessary specialized disciplinary skills*	*Necessary cultivated mindsets*
Analyzing strengths and weaknesses	Objectively analyze a current or future situation or idea for its strengths and weaknesses		
	Detailed thinking		Digging deep
	Holistic thinking		Identifying obstacles
	Unbiased thinking		Understanding tradeoffs
Assessing viability	Determine if the idea going forward will be viable commercially and feasible to make or implement		
	Abductive reasoning	Accounting	Business savvy
	Analyzing strengths and weaknesses	Engineering analysis	Convergent thinking
	Defining the problem		Detailed thinking
	Identifying known and unknown		Futures thinking
	Identifying obstacles		Holistic thinking
	Reframing		Organization
	Understanding tradeoffs		Willingness to fail
Canonical research	Determine the canonical scope of work and understand research within this canon		
	Critiquing		Convergent thinking
	Deductive reasoning		Curiosity
	Digging deep		Detailed thinking
	Identifying core components		Organization
	Identifying key insights		
	Identifying known and unknown		
	Information synthesis		
Creative use of materials	Use available materials in an non-conventional way to represent an idea		
	Defining a goal		Analogical thinking
	Improvising		Creativity
	Representing ideas visually		Curiosity
	Working under time pressure		Humility
			Initiative
			Open-mindedness
			Quick thinking
			Spatial awareness
			Visual thinking
			Willingness to fail
Data transformation	Take abstract data or insights and transform it into something tangible		
	Abductive reasoning	Data analytics	Abstract thinking
	Defining a goal		Organization
	Deductive reasoning		
	Explaining in simple terms		
	Identifying key insights		
	Identifying patterns		
	Information synthesis		
	Story building		
Idea presentation	Present, explain, and possibly sell or defend ideas in a designated session		
	Critiquing		Humility
	Drawing		Leadership
	Explaining in simple terms		Open-mindedness
	Facilitation		Self-awareness
	Persuading		Unbiased thinking
	Representing ideas visually		Willingness to fail
	Story telling		
	Trust building		
Ideating under constraints	Create ideas under specific constraints laid down by the problem or other practical limitations		
	Defining a goal		Analogical thinking
	Defining the problem		Creativity
	Drawing		Divergent thinking
	Representing ideas visually		Quick thinking
	Understanding tradeoffs		Willingness to fail
	Working under time pressure		
Identifying markets	Find new or underserved markets to direct efforts toward		
	Analyzing strength and weaknesses		Abstract thinking
	Defining the problem		Analogical thinking
	Identifying core components		Business savvy

Contextual task (continued)	*Necessary basic skills*	*Necessary specialized disciplinary skills*	*Necessary cultivated mindsets*
Identifying markets (cont.)	Find new or underserved markets to direct efforts toward		
	Identifying known and unknown		Convergent thinking
	Identifying obstacles		Creativity
	Inductive reasoning		Curiosity
			Divergent thinking
			Futures thinking
			Open-mindedness
			Unbiased thinking
Interviewing	Ask thoughtful questions and engage in meaningful conversations in order to understand people's habits, behaviors, beliefs, and other information relevant to the project at hand		
	Active listening		Curiosity
	Clarifying		Empathy
	Digging deep		Humility
	Explaining in simple terms		Initiative
	Facilitation		Open-mindedness
	Improvising		Quick thinking
	Information synthesis		Self-awareness
	Prioritizing		Social savvy
	Trust building		Unbiased thinking
	Working under time pressure		
Layout	Organize information and interactive elements in a pleasing and useful way		
	Defining a goal	Graphic design	Creativity
	Drawing		Organization
	Identifying core components		Spatial awareness
	Identifying patterns		Visual thinking
	Prioritizing		
	Representing ideas visually		
	Story telling		
	Understanding tradeoffs		
Making group decisions	Lead a working group towards a mutual agreement		
	Abductive reasoning	Project management	Collaborative mentality
	Active listening		Convergent thinking
	Analyzing strengths and weaknesses		Empathy
	Clarifying		Holistic thinking
	Critiquing		Humility
	Decision making		Initiative
	Explaining in simple terms		Leadership
	Facilitation		Open-mindedness
	Identifying key insights		Self-awareness
	Identifying patterns		Social savvy
	Information synthesis		Unbiased thinking
	Observing		
	Persuading		
	Prioritizing		
	Trust building		
	Understanding tradeoffs		
	Working under time pressure		
Navigating online communities	Follow leads and links on the internet to discover relevant information		
	Defining a goal		Concrete thinking
	Digging deep		Curiosity
	Identifying key insights		Tenacity
	Identifying patterns		
	Information synthesis		
Need finding	Discover people's needs—both those they say they have, and those they might not even realize		
	Abductive reasoning		Abstract thinking
	Active listening		Concrete thinking
	Clarifying		Curiosity
	Deductive reasoning		Empathy
	Defining the problem		Open-mindedness
	Digging deep		Self-awareness
	Facilitation		Social savvy
	Identifying core components		Tenacity
	Identifying key insights		Unbiased thinking
	Identifying patterns		
	Inductive reasoning		
	Information synthesis		
	Observing		

Contextual task (continued)	*Necessary basic skills*	*Necessary specialized disciplinary skills*	*Necessary cultivated mindsets*
Need finding (cont.)	Discover people's needs—both those they say they have, and those they might not even realize		
	Prioritizing		
	Reframing		
	Trust building		
Noticing what's improvable	Identify which elements of the current design have the most room for improvement so as to focus on those when ideating		
	Analyzing strengths and weaknesses		Abstract thinking
	Critiquing		Analogical thinking
	Defining the problem		Convergent thinking
	Identifying core components		Creativity
	Identifying obstacles		Curiosity
	Observing		Holistic thinking
	Understanding tradeoffs		Humility
			Open-mindedness
			Self-awareness
			Unbiased thinking
			Visual thinking
			Willingness to fail
Qualitative data collection	Collect qualitative data useful in further research or analysis		
	Defining a goal		Abstract thinking
	Digging deep		Concrete thinking
	Identifying key insights		Curiosity
	Identifying known and unknown		Detailed thinking
	Observing		Organization
	Record-keeping		Self-awareness
			Tenacity
			Unbiased thinking
Quantitative data collection	Collect numerical or quantitative data useful in further research or analysis		
	Defining a goal		Abstract thinking
	Digging deep		Concrete thinking
	Identifying key insights		Curiosity
	Identifying known and unknown		Detailed thinking
	Observing		Organization
	Record-keeping		Self-awareness
			Tenacity
			Unbiased thinking
Recruiting and following up with people	Find and keep in touch with a set of people necessary in the design process		
	Trust building		Initiative
			Tenacity
Report writing	Compile a summary that communicates relevant design activities to stakeholders		
	Decision making		Collaborative mentality
	Explaining in simple terms		Convergent thinking
	Identifying core components		Empathy
	Identifying key insights		Holistic thinking
	Persuading		Organization
	Prioritizing		
	Story telling		
	Synthesizing information		
	Trust building		
Resource allocation	Redirect and allocate limited time and resources in the most effective manner		
	Decision making	Accounting	Business savvy
	Delegation	Project management	Collaborative mentality
	Prioritizing		Convergent thinking
	Understanding tradeoffs		Holistic thinking
	Working under time pressure		Leadership
			Organization
Selling	Find the appropriate outlet for a given design and to persuade a stakeholder to buy into the design		
	Analyzing strengths and weaknesses		Business savvy
	Explaining in simple terms		Empathy
	Identifying core components		Humility
	Persuading		Initiative
	Prioritizing		Quick thinking
	Story telling		Social savvy
	Understanding tradeoffs		Tenacity
			Willingness to fail

Contextual task (continued)	*Necessary basic skills*	*Necessary specialized disciplinary skills*	*Necessary cultivated mindsets*
Seeking alternative perspectives	Find the appropriate outlet for a given design and to persuade a stakeholder to buy into the design		
	Critiquing		Open-mindedness
			Unbiased thinking
Stakeholder identification	Identify which individuals and groups (the design team, users, the client, etc.) are most essential to the project at hand and ideate accordingly		
	Abductive reasoning		Abstract thinking
	Deductive reasoning		Concrete thinking
	Defining the problem		Creativity
	Digging deep		Curiosity
	Identifying known and unknown		Divergent thinking
	Identifying obstacles		Futures thinking
	Inductive reasoning		Holistic thinking
	Reframing		
	Synthesizing information		
Survey design	Create an unbiased, comprehensive, and understandable survey tool		
	Clarifying		Convergent thinking
	Defining a goal		Detailed thinking
	Digging deep		Organization
	Explaining in simple terms		Self-awareness
	Identifying core components		Social savvy
	Identifying patterns		Unbiased thinking
	Prioritizing		
	Working under time pressure		
Synthesizing multiple ideas	Take multiple ideas from different sources and synthesize them using the best elements of each original idea		
	Analyzing strengths and weaknesses		Abstract thinking
	Critiquing		Analogical thinking
	Decision making		Convergent thinking
	Drawing		Curiosity
	Identifying core components		Divergent thinking
	Identifying obstacles		Open-mindedness
	Improvising		Visual thinking
	Inductive reasoning		Willingness to fail
	Representing ideas visually		
	Understanding tradeoffs		
Touchpoint identification	Identify all parts of the product or service that the user interacts with or that interact with each other		
	Clarifying		Abstract thinking
	Defining a goal		Concrete thinking
	Defining the problem		Creativity
	Digging deep		Curiosity
	Identifying core components		Divergent thinking
	Identifying known and unknown		Futures thinking
	Identifying obstacles		Holistic thinking
	Reframing		
	Synthesizing information		
Understanding historical trends	Understand the trends that occur over a period of time		
	Abductive reasoning	Quantitative data analysis	Abstract thinking
	Deductive reasoning		Convergent thinking
	Defining the problem		Curiosity
	Digging deep		Holistic thinking
	Identifying key insights		Organization
	Identifying known and unknown		Tenacity
	Identifying patterns		
	Inductive reasoning		
	Record-keeping		
	Story building		
	Synthesizing information		
Use case identification	Recognize the product or service in many varied potential use scenarios		
	Abductive reasoning		Abstract thinking
	Deductive reasoning		Concrete thinking
	Clarifying		Creativity
	Defining a goal		Curiosity
	Defining the problem		Divergent thinking
	Digging deep		Futures thinking
	Identifying core components		Holistic thinking
	Identifying known and unknown		
	Identifying obstacles		
	Inductive reasoning		
	Reframing		

Contextual task (continued)	*Necessary basic skills*	*Necessary specialized disciplinary skills*	*Necessary cultivated mindsets*
Use case identification (cont.)	Recognize the product or service in many varied potential use scenarios		
	Synthesizing information		
Visualizing data	Translate raw data into understandable images		
	Explaining in simple terms	Graphic design	Abstract thinking
	Identifying patterns	Quantitative data analysis	Creativity
	Prioritizing		Detailed thinking
	Representing ideas visually		Organization
	Story telling		Spatial awareness
	Synthesizing information		Visual thinking
Writing for the public	Write summaries and communicate meaningfully with external parties		
	Explaining in simple terms		Empathy
	Identifying core components		Holistic thinking
	Identifying key insights		Social savvy
	Persuading		
	Prioritizing		
	Story telling		
	Synthesizing information		
	Trust building		