AC 2008-2037: CAN DESIGN BE A COMMON GROUND AMONG DISCIPLINES?

Shanna Daly, Purdue University
Robin Adams, Purdue University
Can Design Be A Common Ground Among Disciplines?

Abstract

The act of designing is a complex activity with many facets, including multiple degrees of freedom, context, constraints, and an open-ended and ill-defined nature. Design has often been uniquely associated with fields within engineering, however several design scholars have highlighted that design is central to many fields outside of engineering as well. The artifacts resulting from design tasks may differ significantly from discipline to discipline, but the cognitive activities associated with the task, processes utilized, and negotiation of the design space have been shown to have fundamental similarities. As the global push for interdisciplinary interactions increases, design can be a bridging link for fields traditionally seen as unconnected. The discovery of common ground between disciplines can support cross-disciplinary collaboration and communication and provide an opportunity to improve design education by collaborative research and practice. In an investigation of design experiences of professional designers, common aspects of the experiences were identified as building blocks to establishing common ground. Emerging from qualitative accounts of design experiences by professional designers in engineering, visual and performing arts, architecture, and science were six key themes about the experience of designing. These themes, which were discussed in the experiences of all ten participants in this study, included getting starting on a design, collaboration as a key aspect, the importance of a strong content base, the ever-changing nature of the design space, the role of context, and the challenge and satisfaction of seeing a design task from beginning to end.

Introduction

Design tasks have been classified as specific types of problems, and the design approach has been labeled as a specialized way to view and complete a problem. Design has often been associated with fields within engineering, however a number of authors have highlighted that design is something many people do and central to many fields outside of engineering. The artifacts resulting from design tasks may differ significantly from discipline to discipline, but the cognitive activities associated with the task and the processes utilized have been shown to have fundamental similarities. These similarities have supported arguments to call design a domain unto itself. A domain-independent theory of design has been called an “attractive possibility” as it could provide a common framework for different disciplines, impacting research, teaching, and design practices. While design in each discipline has unique aspects, the goal of this study was to identify the common threads of design between disciplines as a starting point to establish common ground.

The nature of the goals of many engineering projects, both nationally and globally, and within industry and academia, are continually evolving and increasing in complexity. As a result, expertise in a variety of knowledge domains or disciplines becomes imperative. Increased attention has recently been devoted to interdisciplinary interactions and efforts, evidenced by university goals, research studies, and federal funding of...
interdisciplinary projects. \(^{13,14}\) An aspect that has been shown to support interdisciplinary team functioning is common ground, defined as the language and culture that evolves to support communication amongst people in a group. \(^{12}\) As design is at the core of many fields of professional practice, understanding the ways designers have experienced this core activity may help to build a common ground for groups that must design in projects that cross multiple fields and disciplines. The establishment of common ground can foster increased interactions and better communication in interdisciplinary teams, especially in fields that historically believe they are quite different.

Design education may also be enhanced with the recognition that design is a shared experience beyond a single discipline. Educational systems are at the core of impacting other factors that segregate domains of knowledge and practice, and looking beyond design education in a single discipline to design education as an entity unto itself may prove supportive of necessary changes in preparing future designers. Engineers can learn from other disciplines and vice versa about ways to improve design education. A beginning step in this task is establishing an awareness of common practices and experiences in design.

The research was guided by the following questions:

- How do designers within and outside of engineering experience design similarly?
- What themes emerge from these experiences that could facilitate common ground?

Background

Design scholars over the years have proposed a variety of definitions for design. Cross\(^4\) identified design as an ill-defined problem. Visser\(^5\) argued that design involves problem solving, but because of its ill-defined nature, is more than just problem solving. Simon\(^5\) defined design as a “tie between the artifacts and nature” and said it “is concerned with how things ought to be, with devising artifacts to attain goals.” Visser\(^6\) also identified attaining goals in her definition of design: “Design consists in specifying an artifact, given requirements that indicate — generally neither explicitly, nor completely — one or more functions to be fulfilled, and needs and goals to be satisfied by the artifact, under certain conditions (expressed by constraints).” Goals are attained, said Nelson and Stolterman\(^15\) by those who have “the ability to imagine that-which-does-not-yet-exist” and to make it real, concrete, and useful. Thomas and Carroll\(^3\) proposed the idea that design is an approach; fundamentally, design thinking is not a function of a problem, but a way of viewing and managing a problem.

Goel and Pirolli\(^2\) took their definition of design to a more detailed level. They proposed a set of features that they considered to be associated with design tasks based on characteristics and definitions of design previously identified in the literature. They recognized that design was too complex of a task to specify a list of criteria that a design task must have. However, they created a continuum to represent the range of characteristics, described in Table 1, that help classify non-design and design tasks. Their stance was that the more features a design task had among twelve characteristics, the more central the case was to design. If a task did not meet many of the criteria, it did
not mean this task could not be considered design, however it was an example of a less central case. As the design criteria met by tasks lessen, the tasks are considered less central to a design case and closer towards classification as a non-design task.

Goel and Pirolli’s definition provides a framework for this study as well as suggests aspects of design that those of any designing profession may discuss in their design experiences. Goel and Pirolli believed engineering and architecture tasks most closely resembled a design task environment, but thought activities in other disciplines possessed many similar design features. Table 1 illustrates Goel and Pirolli’s twelve features of a design task with a condensed description of each feature. The letters A- L are used to denote each characteristic, as is the style in Goel and Pirolli’s presentation of the features.

Table 1. Goel and Pirolli’s Features of a Design Task

<table>
<thead>
<tr>
<th>Feature</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>A. Distribution of information</td>
<td>Incomplete specification of start and goal state complete unspecification of transition between start and goal state.</td>
</tr>
<tr>
<td>B. Nature of constraints</td>
<td>Two types of constraints: 1- Non-negotiable: nomological (natural laws) and 2- Negotiable: social, political, legal, economic, etc.</td>
</tr>
<tr>
<td>C. Size and complexity of problems</td>
<td>Large and complex; time to propose a solution can take days, months, or years</td>
</tr>
<tr>
<td>D. Component parts</td>
<td>Many parts to the problem, but these parts are not specified by the problem. The designer must decompose the problem.</td>
</tr>
<tr>
<td>E. Interconnectivity of parts</td>
<td>Components of the design problem are not logically interconnected, but contingent interconnections exist.</td>
</tr>
<tr>
<td>F. Right and wrong answers</td>
<td>No right or wrong answers, just better and worse.</td>
</tr>
<tr>
<td>G. Input/output</td>
<td>Inputs are information about people who will use the artifact, the goals that need to satisfied, and behaviors that will allow the goals to be achieved. The output is the artifacts specifications.</td>
</tr>
<tr>
<td>H. Feedback loop</td>
<td>The world cannot provide complete and genuine feedback until the artifact is complete, thus they can only influence the next project, however similar it may be.</td>
</tr>
<tr>
<td>I. Costs of errors</td>
<td>A design mistake can have a high penalty.</td>
</tr>
<tr>
<td>J. Independent functioning of artifact</td>
<td>The artifact is required to function independently of the designer.</td>
</tr>
<tr>
<td>K. Distinction between specification and delivery</td>
<td>A distinction can be made between the specification of the artifact and the construction and delivery of the artifact.</td>
</tr>
<tr>
<td>L. Temporal separation between specification and delivery</td>
<td>There is a temporal separation between the specification and delivery or construction of the artifact. The specification precedes delivery.</td>
</tr>
</tbody>
</table>
Tasks in a variety of disciplines could be considered design based on the features identified by Goel and Pirolli. While Gregory’s view of the similarities of design across disciplines—“The process of design is the same whether it deals with the design of a new oil refinery, the construction of a cathedral or the writing of Dante’s Divine Comedy”—has been called extremist, other scholars have also suggested the variety of disciplines to which design is an essential component of professional activity.

Design literature incorporates a broad range of disciplines in discussions on designers, including those that might not be commonly associated with design by the public. Nelson and Stolterman’s list of design fields included industrial design, architecture, information design, software design, urban design, organizational design, educational design, and instructional design. Cross included furniture-makers in his description of designers. Zimring and Craig noted a variety of other design domains: engineering, architecture, computer science, industrial design, planning, and even the performing arts. Simon called anyone who devised a course of action to promote an improvement a designer. His discussion of professional designers included the disciplines of architecture, business, education, law, and medicine. While Simon did not mention designers of the arts in his initial description of professional designers, he noted later in the same paper that musicians and engineering designers could have an intellectual conversation about the design process.

**Research Design**

This study was guided by the following research questions:

- How do designers within and outside of engineering experience design similarly?
- What themes emerge from these experiences that could facilitate common ground?

Goel & Pirolli’s features of a design task provided a framework that guided the selection of disciplines from which to recruit participants. The detailed nature of their definition of design allowed the researchers to compare typical examples of experiences in a particular discipline to each of the features of a design task.

Thematic analysis was chosen as a guiding research approach framework for this study, as the aim of the research was to identify similarities in design experiences across a variety of disciplines. Thematic analysis is described as a qualitative research method in which themes are primarily induced from empirical data. Repetition of ideas is one indicator of a theme. For this research, the repetition of ideas will appear in different contexts, which made it especially important to look for the key ideas of participants’ statements.

One of the aims of this study was to look for themes in design across a variety of design experiences in a variety of design contexts and compare them to engineering design experiences. Thus, the participants were selected to represent designers both within and outside of engineering contexts. Ten professional designers participated in this study. Participant demographics and their design domain are included in Table 2.
Table 2. Participants

<table>
<thead>
<tr>
<th>Pseudonym</th>
<th>Domain of Expertise</th>
<th>Gender</th>
<th>Years of Experience</th>
</tr>
</thead>
<tbody>
<tr>
<td>Alan</td>
<td>Architect</td>
<td>Male</td>
<td>15-20</td>
</tr>
<tr>
<td>Bill</td>
<td>Biomedical Engineer</td>
<td>Male</td>
<td>20+</td>
</tr>
<tr>
<td>Charlotte</td>
<td>Chemical Engineer</td>
<td>Female</td>
<td>5-10</td>
</tr>
<tr>
<td>Duncan</td>
<td>Chemist</td>
<td>Male</td>
<td>20+</td>
</tr>
<tr>
<td>Evelyn</td>
<td>Civil Engineer</td>
<td>Female</td>
<td>10-15</td>
</tr>
<tr>
<td>Fritz</td>
<td>Computer Scientist</td>
<td>Male</td>
<td>5-10</td>
</tr>
<tr>
<td>Glenda</td>
<td>Dance Choreographer</td>
<td>Female</td>
<td>20+</td>
</tr>
<tr>
<td>Hannah</td>
<td>Fashion Designer</td>
<td>Female</td>
<td>20+</td>
</tr>
<tr>
<td>Isaac</td>
<td>Mechanical Engineer</td>
<td>Male</td>
<td>5-10</td>
</tr>
<tr>
<td>Jack</td>
<td>Painter</td>
<td>Male</td>
<td>10-15</td>
</tr>
</tbody>
</table>

Domain of expertise was one criterion that helped to identify participants, but additionally selection was based on diversifying in terms of gender and years of design experience. Special attention was taken to include a variety of engineers in this study since the research outcomes were aimed to provide implications for engineering education. One factor that also contributed to participant selection was accessibility of individuals. The nature of this study required participants to have a deep understanding of design in their field, thus social networks were used to find volunteers with experiences in design within their discipline.

The framework of thematic analysis also guided the data collection methods. Interviews with participants were semi-structured and open-ended, allowing the designers to recall what they felt was important about their design experiences. The interviews were framed to facilitate participants’ discussion of how they have experienced design in their discipline. The protocol questions began with more structured questions about background, moved into questions about concrete experiences, and ended with open-ended questions about the meanings they associated and important aspects that have stayed with them about their design experiences. Interjected in these structured questions were follow-up questions clarifying word choices, asking for reasons, meanings, and importance, and values. The interview protocol is included in Appendix A.

Results

The results section presents and describes six design themes that emerged from the experiences of the designers interviewed, those of ‘no flash,’ ‘collaboration,’ ‘depth,’ ‘fluidity,’ ‘context,’ and ‘pay-off.’ All designers discussed these aspects of design, but in a way specific to their field of experience. Each theme is supported by a few examples of statements made by the designers. While statements made by each of the designers served to identify the themes, an example from each designer is not included in the reporting of the theme.
Theme #1: “No Flash”
Design ideas do not usually just come as a flash of inspiration. Instead, they build in intuition from previous experience or they are developed by talking with other people, investigating research documents, utilizing past research, or reviewing previous experience.

For example, Alan discussed how tradition is the place to start within architecture, looking at what has been done and how it has been done and using that as a context in which to relate a new design:

So in a sense doing that and breaking completely with tradition leaves you without any sort of relation to tradition which sort of leaves you with non-architecture because you’re left with objects that are not relating to each other because each have their own shape and architectural language and proportions…. It will be a break from tradition or a break from the context that way, but it will still relate to context.

Where Alan had a focus on tradition, Hannah utilized her previous experience as a place to generate her fashion design ideas.

I have a costume background, I was costume mistress for a Ballet four years, so I knew that costumes had to be pleasing from a distance, beautiful or at least engaging. They had to communicate a feeling but they also, like dance costumes, had to be indestructible because they get manhandled. So I used that in my construction.

Charlotte also focused on designing based on her previous experiences in chemical engineering as well as using the company’s previous design products:

I started by – I had experience in a similar kind of setting, so I thought about what it would look like in the setting that I was used to. I pulled all the documents listing the customer’s specific requirements, listing the general quality systems requirements and then also pulled all the documents for the way the plant had run before even though it was going to be a different set-up now, I thought that there might be something in what had been done before that would be helpful because some of the management folks that we hired, we hired back. I knew they would remember the old way whereas I was used to a new way. So I knew I needed to blend them. I guess I started by pulling all the documents...

Isaac had a similar viewpoint about using other people’s work as a baseline in his mechanical engineering design experiences:

Isaac: You’re never really starting from scratch in design so it’s always good to look at what other people have been doing. So I started with some papers that other employees had written on heat generation within motors.
Both Glenda and Evelyn discussed the value in seeking out similar work done by other designers in their field, dance choreography and civil engineering, respectively:

*Glenda:* I feel like watching other people’s choreography really helps me figure out what I need to do in my design process.

*Evelyn:* I would go looking for something that was similar to what I was about to do and if that worked out, you know, it would probably be a great starting point. Again, with the homework, I would go and find someone who had done my problem before and see what was different about it and go from there.

All of the designers talked about the use of precedence as a starting point to their design approaches. Previous work and experience and expertise from others often provoked thinking, which could lead to a creative outcome.

**Theme #2: “Collaboration”**
The design experience is not something that is done alone and in isolation. Collaborators have a pivotal role in a successful design, in the form of suggesting ideas, giving feedback, and validating ideas. In many contexts, they can also be a barrier if ideas are not communicated as grounded and as a potential way to a solution.

Charlotte felt strongly about utilizing people as resources throughout a design experience, which includes experts, but also those that would utilize the design:

*You can’t go it alone and it’s important to get input from other people and to get input sooner rather than later. I might think that I have a great idea, a great way to do something, but if I’m not the person doing to every day, surely there are things I don’t understand. Sometimes it takes somebody pointing out the obvious and saying, duh, you forgot that we have to do X Y Z. Oh yeah. So getting input earlier in the process and not try to shoulder the whole burden of design. I think designing means to be a team; it needs to be “we”. "We" needs to be the people that are going to be using it, implementing it and working with it. Those are the folks that suffer when it doesn’t work. It is important to go outside the group of users as well to get a fresh perspective...I think it’s hard sometimes to ask for input and feedback especially if you’re really, really certain about what you’re doing, then you may not want someone telling you it’s bad. If you’re very uncertain about what you’re doing, it feels kind of awkward to say, come inspect me, come criticize me. What I learned was asking for help often and that it’s okay to just say, here’s what I’m thinking. I didn’t have to have a finished product to show somebody. I could say, here’s my thought processes is going, what do you think?*
Hannah and Glenda also talked about the role that feedback from others played in their design processes:

Hannah: You get to learn how other people view things. We were both looking at the same play, but they took a different take on it. We meshed our ideas for the outcome and a collaborative approach is nice... Butting heads gets you nowhere. You can state your view and they can state theirs, but in the end, it's collaboration. I'm not territorial, I'm open to other's viewpoints and that helps.

Glenda: You don't always see it and that's why you have other people look at your choreography. Sometimes you're so into it and it looks so cool, but you don't realize that it's flat, it doesn't have any dynamic shape to it... And a movement could be saying one thing to you but it could mean a totally different thing to someone else. And not that you have to change it, but it might not be saying what you want it to say and you can't see it because you're too close to the process. So I like to hear what people think it's about or what it makes them feel so that I know whether that's really what I want to say. Maybe the movement is fine, but it's not saying what I want it to say and then I usually go back because I really want it to say something, if that's important to me. Then I change the movement.

Bill agreed that multiple perspectives were crucial to his success as a designer in biomedical engineering, but pointed out that there is a balance between the right number of perspectives and too many:

I don't know that everyone works as a team that way, but it's a way that I work best. It is when a group of people who have similar goals but different perspectives, try to solve a problem together and the design process, again, if it's an iterative process where you're bringing in innovation and more improvisation, and using intuition to guide some of that, people's different experiences can bring different, unique, perspectives or elements to that process. We would meet very regularly to talk about where projects were going but perhaps more importantly, we worked in the lab together and so when I mixed a and b together and changed the temperature and the pH and made this funky reaction that looked sort of like we liked, I ran into the other room and said, Hey, look, this worked and this is what I did... Sort of look at it from a number of viewpoints and having those multiple perspectives I think opens up the possibilities and makes it a richer environment for improvisation, for structured, guided improvisation, and ultimately for the design process. I think the third party objective critique comes in at some place because you can get down a path and get tied to a creative process or a process that you've created and it gets you to a point that's close, but it's not exactly, and ultimately to get there you might have to back up but you it's hard, you get married to the process that you've created and you can't see that
there might be another branch. You could have done this or that and I think it takes another person to say, not unlike reviews that we have after showings, you need someone to say, that was really cool, but I didn’t see this or you could have done that. You don’t think about it if you don’t have a more objective third party… As someone has said, the best designs are never done by committees. The idea that you can really only make incremental change, smaller change, if the constraints are tighter or narrower. Having so many people giving oversight and the path being fairly clearly constrained, the options we had led to a more incremental kind of creative design. Fewer people, broader perspectives, can lead to much more diverse kinds of outcomes.

Isaac did not advocate a “committee approach” to design, but felt that the more people that could be involved in the design process along the way, the better the outcome:

In a broad sense, to keep in mind all the players in the different constituents. The customer is an obvious person to include, but again, there are people like vendors who are good to consult with, fabricators, and all these other players. Involve as many people as you can, even people who aren’t even part of your design team or company. That would be my biggest piece of advice.

Alan discussed how often times collaboration in his architectural design experiences means having to convince another person to move forward with an idea:

[The design experience] also taught me a lot about having to convince other people and about communicating your ideas to them because for example, the construction engineer had an idea about how to put the new columns on the existing base and I thought it looked like crap. So I came out with an idea of how to put some sort of an elliptical base and in that base putting the new columns so you have something that connects the old, existing and the newly planned and not just sticking something into something in very simple way just to do the stuff that you’re supposed to do. First he said, it can’t be done and then he said, it’s not structurally true, and then what I did, I built a computer model of that thing… I took him to the screen and I told him this is how I picture it, doesn’t it look pretty… And by doing that, by showing him, by communicating to him exactly what I want to do and by showing him how architecturally correct it is to do exactly that, I got him to do his job. If I just insisted, I want it that way, like a crying baby, it would never have done it. But if you want to convince people, you have to communicate your idea to them in more than one way and you once you convinced them to work your way, they’ll do everything and he was very collaborative from that point on. But first, I had to convince him that what I was doing was the right thing to do. Because I had it all in my mind, but he didn’t have the same mind and I had to take this idea out of my mind and put it the pensive and let him look
into the pensive. And this is communication and this is what I speak about collaborative design because you never plan a building on your own.

**Theme #3: “Depth”**
This theme emphasizes the importance of having a strong content base. Content helps build intuition. Content helps build intuition, and helps designers make informed decisions between varieties of alternatives.

Fritz talked about the content background that he had and how in his computer science design experiences, it has shown to be very helpful to his design successes, so much so, that he believed it to set him ahead of other designers without such content background.

For my kind of design, I would say, when people in my industry go through school, they try to take courses to get their degree and with me, I wanted to take more courses than I had time for because the more you know about something, the better off you’re going to be. I would say take a lot of math. There’s a lot of math involved. Computer science and math, they go hand in hand—double major or minor in math. It’ll help you out vastly. On just a day-to-day basis of being about to calculate numbers in your head when you’re developing something, when you’re converting from seconds to milliseconds and nanoseconds, it helps a lot. But not only that, when you’re dealing with software, again, scalings a big thing, being able to support for your users. Math is hand-in hand with it. So I would say math is definitely bypassed by a lot of computer scientists. It gives you a very large leg up on the competition.

Bill and Duncan, who associate themselves with biomedical engineering and chemistry, respectively, talked about times in their professional design experiences when they made decisions guided by their content knowledge.

Bill: You learn by experiencing and absorbing lots of information in that particular area where you’ve lived for awhile. I’ve spent a lot of years playing with biological stuff causing them to interact for various reasons, for better or for worse, saw how proteins interact and had some concept and that’s the intuition that I was using in this particular area.

Duncan: The initial set of experiments was pretty standard textbook chemistry. We had a material and we had to identify what it was. This was something that any organic or analytical chemist can do. They’re well known techniques. There’s mass spec, there’s NMR, there’s IR, there’s UV. That’s what we did. Once we got to that point where we knew what the material was, then came the theories in terms of how we should solve this.

Glenda talked about using the core concepts in her discipline of choreography to make changes when the dance design was not communicating what she wanted.
To me, if it’s too flat, like the dynamics are too flat -- so you use those tools of choreography to change the dynamics. You use tempo, you use level changes, you use direction changes. All those tools of choreography, if you can somehow incorporate like isolating a body part to elicit an emotional response. Just one little tiny movement over and over, repetition. And again, spacial design. Could you move the dancers around and then have them stand in one place? Could you change their level and do the same movement, but what if it was on a different level? I guess, I know when it’s boring, when I go (sigh). When I’m starting to let my mind drift. Oh, that’s not what I need there. You don’t always see it and that’s why you have other people look at your choreography. Sometimes you’re so into it and it looks so cool, but you don’t realize that it’s flat, it doesn’t have any dynamic shape to it, but usually the element of time is a really important tool to manipulate because a lot of our movements even-steen.

Theme #4: “Fluidity”
Designs constantly change throughout the design process. Often they are small changes but sometimes they can be big changes. It is not a linear process like it is sometimes presented in design classrooms. Rather it is something more fluid and open to both change and uncertainty.

Alan, Evelyn, and Charlotte described their design experiences as constantly changing in architecture, civil engineering, and chemical engineering, respectively:

Alan:  And about fluidity, things are not stable because this is what I learned form my boss… I don’t want to say anything about whether this is good architecture because it’s not my place to do that, but as a way of doing things, it seems as if what we saw in these tapes was that there was an image selected for the building and the building didn’t change dramatically from time to time, just minor changes. Add ten more centimeters for this space, move that space just a bit, add two more seating places. This is stable. What I learned form my boss is the other way around. If you want the outside milling area bigger, then just extending the canopy wouldn’t do that, you have to do something else and add something else and maybe that will change the inside of the chapel. Just so that you can relate to things that you maybe saw and heard and know from these tapes… As long as it’s on paper, everything can be changed.

Evelyn:  But this project actually started as just a deck replacement. It was going to be a tempered deck replacement on this two lane road and it started even before I started at that company. Then just kind of through evolution they decided this is a major thoroughfare in the county and it
should probably match up with what we expect the traffic to be and so it turned into this enormous bridge replacement project.

Charlotte: It was just amoeba-like, just the boundaries just kept changing whereas the making a process change, that was a pro-active kind of thing.

Jack and Glenda also experienced a lot of changes in their design experiences in painting and choreography, respectively, and much of that they attributed to the uncertainties that existed within the projects:

Jack: We can only guess so far beforehand and then you have to change things in the middle… Honestly, sometimes so many accidents just add up and I think you start to notice what accidents are going to be useful to you as a designer.

Glenda: I never knew what was going to happen and so that was scary and there were several rehearsals where what we created did not work and so I kept having to go back to zero and that’s frightening when we only have few rehearsals.

Theme #5: Context

The context of the design is vital. Without this context, designs are disconnected from other designs that have gone before. Without context, designs cannot do what they are supposed to do as well as they can.

Charlotte and Alan discussed the people that would be affected by the design that they implemented:

Charlotte: So I had to design how the system was going to work, taking into account that we only had probably four salaried people working and the hourly workers were not at all familiar with processing aluminum parts. Some of them had just come from previous jobs at places like Wendy’s and McDonalds and so here they were in a very different situation and knew nothing about what they were doing. So I had to design a system that was going to work, had to be implemented fast and be approved by customers for all affected customers and to audit what the system was going to look like and make sure that it met their internal requirements.

Alan: This is how you do it – you just keep drawing, keep trying to imagine how things will look, either in perspectives which I believe readable to everybody. You have to know what you do in order to understand what you do or detailed sections of different places at the house. And you always try to relate these to people. Let’s not say people, because let’s say you design a dog shed, you have to draw the dog inside of that so that you will compare what you’re doing with the subject that’s
going to use it. So if it’s people, I draw people in it so that I can understand if it’s wide enough, tall enough, big enough for people.

Fritz discussed the context of the computer science situation in which he was designing, where he had to take into account what was already there, and build upon it:

*The other challenge is that when you improve something, especially in security, you can’t break what’s already there, so you need to improve on it, make them both work until all the data just kind of works itself out, until this user logs in and then we say, you need to change your password as things progress.*

**Theme #6: Pay-off**

There is a satisfaction in the completion of a design, leading to a passion for doing more of it. It is also a challenge, but pushing through the challenges will instill confidence and a greater pay-off to the designer.

Evelyn talked about the personal satisfaction she felt from seeing her civil engineering design go to completion:

*Although it’s scary and unknown, it’s the really cool stuff when you’re done because it gives you that self-confidence when you’re finished even though half the time you’re floundering. But it also made me realize that no one else can do this either and so the ability to say, I don’t know how to do this and to seek out the people who can help you, I think is a big part… There is the possibility that you can start a project and for whatever reason, whether the project stops or you go from one consultant to another, you’ll never see it constructed. And that is unfortunate because there’s a lot of satisfaction in starting something and then seeing it go to construction.*

Jack felt that accomplishing the challenges in his painting design experiences made him feel more confident in himself and his abilities:

*I also learned that I could paint big which is something that I hadn’t quite believed yet. I’d never gone that big before and it was frustrating at first and rewarding at the end… For me, being aware that I’m capable of designing and that I’m up to that makes it richer for me and makes me feel like I have a place in the world… Being aware that I’m allowed to design those things, gotten lucky enough to be in a position to do that gives me ownership and pride and also sorts of reasons to feel my way toward doing other good things.*

Bill discussed the challenges and the excitement of meeting those challenges in his biomedical engineering design work, and said he had so much joy from doing it that it became his approach to many aspects in his life:
I would have to say that for me, the most satisfying thing that I do in my life is related to design. It’s the way I approach almost every job I’ve had and when I’m not working, it’s the way I approach almost everything else in my life. Creating new things, designing new things, finding new solutions is enormously satisfying to me. Challenging as well. It’s the way that I best or most enjoy being challenged. So the role is that it provides satisfaction, enjoyment. On the other end, you could say in a practical way, it’s how I make my living. I was hired to design and implement this curriculum. Previous job I was hired as a consultant to do design solutions for companies. Prior to that, I was a research associate in engineering and was paid to do design and there were days that I thought I shouldn’t be paid so much to be having so much fun.

Alan felt architectural design was so much a part of his life that that it sparked a desire in him to do more.

It’s also a sickness. Once you start doing it, you can’t stop doing it. Do you have architect friends or have you ever been to a new place with architects? It’s a mental sickness. Now I’m with you so I’m a bit shy about it, but if I go into a place that I’ve never been to before and I see something that interests me like the way that the door is connected to the wall or maybe the way that this glass wall is built and I see that it has seemingly has no construction in it and I would go and would start picking it with my fingers and I would start looking at it and ask myself how did they do that, how did they fix it to the floor, to the ceiling, what’s the detail, what’s behind it so it will not fall. When I look at inside here I can see that they put some lights in a gap between the ceiling and the glass wall so I guess at night time there’s like a bluish streak of light surrounding this wall and they have blinds so they can close this room and how did they fix these blinds to the wall. And is that the most elegant way of fixing these blinds into the wall. The could have fixed these blinds in the gap between the ceiling and the glass wall so that I will not see them...So maybe did they want me to see them or did they not want me to see them and think about it. So you see it’s a sickness.

Discussion

This investigation began with two questions in mind:

- How do designers within and outside of engineering experience design similarly?
- What themes emerge from these experiences that could facilitate common ground?

What emerged is that the designers interviewed, while the content and contexts of their experiences were quite different, talked about the nature of their experiences quite similarly. This suggests that there is some form of common ground among ways of
experiencing design. In other words, engineering designers, architects, visual designers, and scientists could sit in a room together and have an intellectual conversation about what it means to “do” design and “be” a designer.

The similarities that emerged from this investigation reinforce an argument that design may be a domain unto itself, where the six common themes (‘no flash,’ ‘collaboration,’ ‘depth,’ ‘fluidity,’ ‘context,’ and ‘pay-off.’) may represent aspects of this domain. This suggests that design stretches across disciplines where aspects of experiencing design are similar no matter the disciplinary context. The experience of designing holds these disciplines together.

The common ground that may be built among these disciplines can be described from the themes uncovered in the design interviews. These include the relationship between design tasks and outside factors (collaboration, context), design knowledge (no flash, depth, fluidity), and passion (pay-off) for design work.

The designers interviewed talked about collaboration as an essential part of design, that design does not happen in isolation. While this might be expected, it is also surprising given that some of the designers interviewed might be described as people who “work alone”. Collaboration was viewed not just as working together in a design team but also working with and engaging others who become crucial resources for a design project by providing feedback and alternative perspectives. However, like many other aspects of design, collaboration was something that had to be managed.

Context was a strong consideration discussed by all designers, as they focused on those who would be affected by the design as well as taking into account any existing design. Each saw context playing an important role in what characterized a “good design”. A stand-alone design out of context could be of the highest quality, but without an awareness and attention to its context, the design is likely to fail.

Designers also discussed aspects of design that represent a kind of design knowledge: precedence, content background, and the fluid nature of design tasks. The themes “no flash” and “depth” speak to a kind of design knowledge and how designers learned from experiences. The theme of “fluidity” brought awareness to the ability of the designer to be aware to the changing nature of design tasks, and adapt to new boundaries. While the nature of precedents, content, or contexts differed, all of the designers spoke of the nature of design knowledge in a similar manner.

Design professionals saw design as based upon precedence, including previous experiences of the discipline, previous experiences of the company, and previous experiences of the designer. The theme was called “no flash,” and revealed the role of intuition built from previous experiences as well as developed during the course of the task by talking with other people, investigating research documents, utilizing past research, and reflecting on their previous experiences. This speaks to the role of experience, tradition, and history “doing design” and “being a designer.”
The theme of ‘depth’ emphasized designers’ stance on the importance of solid content background in the discipline. Designers stressed the importance of depth of knowledge. While there are certainly skills associated with design tasks that are separate from content knowledge, content knowledge is a foundation for decision making. Content knowledge helps build intuition, and informs designers in their solution-generation processes and making choices among alternatives.

Design experiences had fluid and changing boundaries, goals, contexts, and collaborations. Therefore, designers emphasized how important it was to them to have the ability to adapt as those changes occurred. Often, changes are small, but sometimes they can be big. A rigid and process-oriented approach was not often the reality in design situations, therefore, it was considered important for designers to be flexible and open to changes. The discussion of the fluid nature of task suggests that approaches to a design solution are achieved through iteration. It is not a linear process like it is sometimes presented in design classrooms. Rather it is something more fluid and open to both change and uncertainty.

Design, by its very nature, is an activity done by humans. Professional designers spoke of the personal affective payoff of succeeding in an experience filled with setbacks, challenges, and uncertainties. Sharing a passion is a building block for the development of common ground.

Lave and Wenger\textsuperscript{19} spoke of passion and commitment to the domain as one of three central ideas that hold together a community of practice. The designers interviewed in this study were personally connected to their designs, and discussed their passions for doing design both within and outside of the context of their work. The other two factors impacting communities of practice discussed by Lave and Wenger were community and shared practices. Shared practices relate to design knowledge in the themes of fluidity, depth, and no flash. Supporting the building of a sense of community around design is a motivation for this research, and an awareness of similarities, as revealed by the designers in this study, is a starting point for the development of this community.

The themes that emerged from this investigation also provide new insights to Goel and Pirolli’s\textsuperscript{2} framework for characterizing the nature of design tasks. A number of connections became evident in the course of this investigation, as well as some important differences. Of the themes discovered about the nature of design experiences, the themes of context and fluidity can be linked to Goel and Pirolli’s features of a design task. The input/output (G) feature of a design task included context and is related to the ways the designers discussed the contexts of their tasks. The fluid nature of a design task relates to the nature of negotiable constraints (B), because as constraints are changed or manipulated, the approach to a design task may change course. However, Goel and Pirolli’s features of design task do not incorporate the interface between the designer and the task. There is no link in Goel and Pirolli’s framework to precedence, collaboration, depth, or personal payoff. While their framework does speak to some aspects of the context of design, it does not give adequate voice to how design is experienced in terms of affect, tradition (precedence and depth), or the social aspects of design. It seems that
their characterization could be expanded upon to include features of the design task that incorporate the designer. This research has uncovered significant aspects of the nature of the design experience, including the role of the designer, and not just the task isolated from the interface with the designer.

The results of this study have implications for design practice, as the recognition of commonalities may facilitate designers of various disciplines to work together effectively. One way this can support design practice is by designers sharing stories of experiencing design. This may play a role in cross-disciplinary collaborations, where those involved can make connections among different, yet very similar, ways of experiencing design. Sharing a passion about the experience of design can go far in creating common ground. As design is a complex activity, sharing stories may also provide new perspectives on different approaches to addressing the challenges of collaboration, uncertainty, and other aspects that constitute the nature of design. Additionally, common themes might be used to create trust and credibility in cross-disciplinary design situations; if all see design as uncertain, collaborative, contextual, etc., then there is some level of trust in how they could approach design as a group. This study has implications for engineering students. The ways they experience design in different contexts can be a place for reflective practice when thinking about engineering design. In other words, if an undergraduate is taking courses in dance choreography, this can have an important, and positive, influence on how that student comes to understand engineering design.

Conclusions

This paper presented the preliminary results of a study conducted on design experiences of professionals within a variety of disciplines. A cross-case analysis of the personal accounts of these experiences identified six themes running throughout the experiences of all of the professional designers: ‘no flash,’ collaboration,’ ‘depth,’ ‘fluidity,’ ‘context,’ and ‘pay-off.’ This study starts to show aspects of design that can support common ground among disciplines. It also has implications for understanding the practice of design, perhaps providing evidence to expand upon Goel & Pirolli’s definition of design. This study also has implications for interdisciplinary design practice, suggesting that designers working together from multiple disciplines work to become aware of common links, share experiences and look for connections, recognize design knowledge and tools apart from their context, and enjoy that they have common passions.
References
Appendix A: Interview Protocol

Field Background and Word Choices

- During our conversation, I’d like you to talk to me about your experiences designing in your field.
- Before we get started, can you tell me what it means to you when you use the word design?
- I use the word design, but there may be a word that you are more comfortable or familiar with when you describe your design experiences. Is there a particular word or phrase that you would use that describes what it means to design in your field?
- What do you consider the field of work that you design (insert their word of choice) in to be?
  o If the interviewee needs prompting:
    - What discipline do you associate with?
    - What do you call yourself? Why is that?
    - Do you call yourself that when you’re describing what you do to other people, you are a (insert disciplinary title, i.e. mechanical engineer, business owner, choreographer, etc.)?
    - What field is your background in? What area have you been trained in?
- How long have you been involved with design (insert their word of choice) in (insert field)?
- Do you have any formal training involving design (insert their word of choice)? What did that involve?

Describing Experiences

- Can you tell me about an experience you have had designing (insert their word)?
- What did that experience involve?
  o These questions are asked if the interviewee needs more prompting:
    - What was the goal?
    - What were you designing?
    - Who were you designing it for?
    - Where were you designing?
    - Who else was involved in the design experience?
    - What was your specific role in the experience? What were your responsibilities?
- How did you approach the task from beginning to where it is now? Can you walk me through the way you went about doing it?
  o What did you do?
  o What led to that?
  o Why did you do that?
- Did your approach change over the course of the project?
  o If so, how and why?
- Did you learn anything about designing from your experience?

Comparing Experiences (If time permits and depth has not been reached)

- Can you describe another practical experience you have had designing in your field?
o How do you think this is different from the experience we talked about earlier?
  o Did you approach this project in the same way as you approached the previous one we discussed?

• Are your strategies for approaching a design task similar across tasks or specific to the task? How so?

Further definitions
• We’ve been using (insert word) to describe designing in (your field). Based on your experiences that we talked about today, what is design to you?
  o Has that changed over time?
  o Was there a particular time or experience that prompted that change?
• What role would you say design has in your life?
• Has what design means to you personally changed over time?
• Based on what we talked about today, are there ideas or recommendations you would have for design education?