# Designing for Communities: The Impact of Domain Expertise

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# Designing for Communities: The Impact of Domain Expertise for Playground and Engineering Experts

## Abstract

In support of ABET's goals for engineering students to achieve greater skill in broad thinking and contextual awareness, this paper illustrates how domain-specific experiences may be helpful for one's ability to focus on social and human-related factors in a design process. Utilizing data from four playground experts and five engineering experts given the task of designing a playground, our research found that participants with domain expertise (i.e., playground experts) were inclined to consider context (especially socially oriented factors) more often, regarded actors and their use of the playground equipment in a holistic manner, and almost exclusively used professional domain knowledge rather than personal knowledge. The results of this analysis point to the experience required to incorporate broad thinking in design solutions.

## Introduction and Background

Our research seeks to understand the relationships between the possession of expertise in a particular domain and the potential accompanying ability to situate problems and to think broadly during the design process. A domain is defined as a shared system of knowledge and activities that focus on a particular subject, and expertise "…refers to the characteristics, skills and, knowledge that distinguish experts from novices and less experienced people."[1] Gaining domain expertise involves an amalgamation of experiences that have led a person a person to achieve a particular level of skill and knowledge.[2] The path to achieving domain expertise can be a complex and difficult one that begins, simply, with gaining professional and educational experience.

Gaining experience leads to engineers often being tasked with designing projects that demand consideration of local, regional, and even global communities. Such projects may be situated in complex spaces, requiring both technical expertise and an ability to consider broad contextual issues. While the beginning engineer relies predominately upon their educational background; expert engineers hold experiential knowledge in their domain of expertise to aid them in considering a broader array of factors. ABET, the engineering accreditation body, specifically states in Criterion 3h, that engineering programs should help engineering students achieve the "the broad education necessary to understand the impact of engineering solutions in a global, economic, environmental, and societal context."[3] Teaching these skills to engineering students is a challenging task, but one that is critical if engineers are to design for the benefit of the many communities for whom they work.

Many hours of practice and experience are essential for gaining domain expertise.[4, 5, 6, 7] For engineers, the primary introductions to their disciplines are encountered through education, and as such it is important that engineering programs provide students with a realistic and expansive understanding of the field. Leckie[8] observed that undergraduates in general are often kept in the dark about important aspect of the disciplines within which they are studying:

> The students have no sense of who might be important in a particular field… They do not have the benefit of knowing anyone who actually does research in the discipline (except for their professor) and so do not have a notion of something as intangible as the informal scholarly network.

Developing a general sense of how a discipline works is essential to gaining expertise and being situated within a community helps to enable this. Lave and Wenger suggested that where individuals are socialized in an environment that is co-constructed by its participants; where they learn, participate, further their particular community, and are able to modify the implicit and explicit rules that guide them on their way; they form communities of practice.[9] Gaining disciplinary experience, including familiarity with the vernacular of the domain and various cultural artifacts and processes is the motivation for placing students in apprenticeships and internships. A first step in distinguishing oneself as an expert is often the "insider" knowledge that is gained through those kinds of experiences.[7, 10]

As experience in a domain increases, methods for efficient participation begin to surface, and new mental capacities are developed. The knowledge gained through hours of practice, education, and involvement in community is more expertly organized into larger chunks.[11, 12, 13] This chunking of knowledge allows for some cognitive tasks to become automated,[14] thereby leaving room for higher levels of cognitive activities, capacity to attend elsewhere, or focus on other issues.[11, 15] This research in expertise provides a different perspective on the ways that engineering education fosters, or (at minimum) primes our graduates for the cognitive development of expertise that results from being situated within an engineering domain.

Many engineering programs in the United States focus on providing a superior technical education to engineers. Not much focus is given to teaching students to connect broad contextual issues to the problems they are solving.[16] Kazerunian and Foley[17] stated that most engineers are not being offered an education that values creativity in their work, which has impacted breadth of thinking for engineering students. Educators, far too often, promote narrowly focused, prescriptive design methods over providing opportunities for students to explore larger issues and new ways to think about engineering practice. As one example, in the year 2000, 80% of engineering programs did not include ethics-based courses aimed at broadening engineering student thinking. Only a subset of the remaining 20% of institutions included engineering ethics courses, and the others relied on courses in the social sciences or philosophy.[18] As professional and educational organizations began to realize the need for engineers who could think more broadly, research was enacted that explored how engineers approach their work and carry out design projects, with the idea that educational change should be driven by solid research.

Kilgore et al.[19] found that first-year engineering students, when asked to work a design task, considered contextual factors that were aligned with their current knowledge, and were less likely to leave their comfort zone. This is also aligned with Ahmed et al's[20, 21] work, that found that novice engineers were unlikely to ask relevant questions due to their limited experience, sticking to what they know. Ahmed et al. found that engineers were less inclined to follow particular design strategies, since they were unaware of their existence. Kilgore et al.[22] also discovered that while undergraduate engineers were considering different aspects of the lifecycle of a product, their considerations were tied to the strict engineering design process. Atman et al.[23] found that engineering students, when asked in interviews to address a particular topic, addressed slightly more technical concepts than other majors, who addressed social topics more often. This research also found women were considering more contextual factors than men, based on personal interests and ways of knowing. Additionally, Atman et al.[24] found that senior engineering students were considering a broader array of contextual factors over freshman in the problem scoping phase of their design process. Thus, Atman et al.[24] recommended students be presented early on with more real world teaching curricula to introduce them to a variety of situations for increased comfort with varying ideas.

The above research leads us to consider how engineering educators are teaching their students design, and how the complexity of engineering problems that are found in professional practice may be better situated in engineering curricula. What follows is a brief discussion of two pedagogical models; Project-Based and Problem-Based learning, that are now found more often in engineering education and may provide the necessary framework for addressing the types of context and community oriented solutions that are the focus of the research we present below.

*Project-Based Learning*

Project-Based Learning (PBL) is an experiential mode of teaching that directly addresses the development of expertise through increased number of hours in-situ.[25] There are several specific features of PBL that have made it successful. Engineers are involved in capstone engineering projects where they experience the importance of issues relating to the sociality of a particular environment and learn the impact of contextual issues as they move through the project. PBL students are grouped with people from diverse backgrounds, allowing multiple perspectives on a given subject through interactions among group members. Engineers learn to work across disciplinary lines as a result of group work. Implementing these community based projects early in education, provide experiences to students that lend to continued thinking in areas of community and other contextual concerns. PBL also addresses one of the key issues in the cognitive sciences: *transfer*, which may be defined as the ability to extend what has been learned in one context to other, new contexts.[25]

*Problem-Based Learning*

Problem-Based Learning (the other PBL) has been shown to increase participation and interest in engineering when used as a teaching method, over lecture-based learning.[26] Unlike Project-Based Learning, Problem-Based Learning has no correct and final solution as the goal of the educational endeavor. Problem-Based Learning may also be used in a shorter term to help students understand specific ideas in their discipline.[27]

There are several models of Problem-Based Learning that seek to help educators more easily implement this as a teaching practice into their curriculum.[28] Differences in applications and organization of Problem-Based Learning deal with differences in how students are able to transfer the learning outcomes of the teaching style to other areas of their education. While students do not necessarily need to be in groups, Problem-Based Learning may encompass working with communities, or obtaining information about various populations which helps them to alter their learning and thinking practices.[28]

## Methods

This study adds to a series of studies done by researchers at the Center for Engineering Learning & Teaching (CELT) on engineering design processes. That prior work utilized the same playground design task wherein engineers, with varying levels of design experience, were asked to think-aloud while designing a playground for the community in a fictitious neighborhood in a three-hour timeframe. The methods for these studies are described elsewhere[29, 30, 31] and will be summarized briefly here. Participants gave a verbal protocol while they solved the problem. An administrator was available during the session, keeping time, prompting participants to “keep talking” if the participant fell silent. If a participant requested additional information the administrator would provide information from a broad set of categories, for example: budget, neighborhood opinions, specifics about the area, or materials costs. The sessions were video and audio-taped, and the audio tapes were transcribed. The transcripts were segmented into idea units (independently segmented by two coders, reliability checked, and discrepancies resolved by consensus). Previous analyses of these data were conducted by assigning a code based on a pre-determined coding scheme of the engineering design process.

Each participant produced a playground design. The quality of the designs was assessed using a score comprised of three components, which added together resulted in a score ranging from 0 to 1. The first component consisted of seven criteria included in the problem statement plus an additional 33 criteria from a guide to playground design.[32] The second component included scoring each solution based on diversity of activities; aesthetics; protection from injury; uniqueness; and technical feasibility. The final component included specific assessments of the individual playground components that were included by the designer (for example, slides, sandboxes, swings). Methodological care was taken to ensure the reliability of the quality scoring as well to ensure compatibility between the student and expert studies (more details can be found in [31]).

Earlier research included first year engineering students (n=26), graduating engineering students (n=24) and expert engineering designers (n=19) as participants. These studies found differences across these three levels of engineering expertise in terms of overall time spent, problem scoping, information gathered, design activity transitions throughout the design process, and design quality.[29, 30, 33] Data from expert playground designers (n=4) were collected in the same time period that data from the expert engineering designers were collected. Experts for both groups were identified by their peers as expert designers in their field. This paper presents the qualitative analysis resulting from the playground expert data and from a subset of the engineering expert data.

A qualitative coding analysis was completed by a singular graduate research assistant who was purposefully provided no details regarding the goals of this study, and had not read any papers related to CELT's previous playground analyses. This approach supported an inductive or "open" coding analysis, allowing themes to emerge from the data.[34, 35] Initial stages of coding involved a read-through of content to generate preliminary codes, followed by three iterations of application that involved code addition, and altering code applications, nomenclature, and definition. Revisions were further supported as codes were discussed in CELT research meetings to clarify definitions and application. Finally, in order to ensure the replicability of the coding scheme, a senior researcher coded two randomly chosen participant transcripts for each expert type.

The qualitative data from the coded transcriptions were then counted and entered into Excel spreadsheets to create visualizations that showcased each instance of a code on the full three-hour timeline of the design task. These visualizations were used as tools to uncover themes and patterns in the data. The code categories discussed in this paper are: context (environmental, social, economic, political); people (actors, use); and knowledge (professional, personal). More specific code definitions will be discussed below (Table 1) and in the findings section.

Table 1: Code list and definitions

| Code | Definition |
|---|---|
| Context | The overall setting and background of project |
| *Environmental* | Physical environment in which the project takes place |
| *Social* | Relationships in the project area |
| *Economic* | Relating to money and business |
| *Political* | Relating to government and policy |
| People | Elements relating to humans along with their needs and use of space |
| *Actors* | Human actors involved in building or using the playground |
| *Use* | Use of the playground by human actors |
| Knowledge | Familiarity with a particular topic based on an amalgamation of experiences and information |
| *Personal* | Based on experiences from similar tasks or personal life |
| *Professional* | Knowledge gained from professional education and training |

## Sample

The participant sample included for this analysis consisted of five of the original 19 engineering experts (E) and data for all four playground design experts (P). Table 2 presents a summary of the participants. Note that the pseudonyms for the engineering experts start with "E" and the playground experts start with "P". The five engineers were selected from the 19 to both show breadth of solution quality and to match the high quality design scores displayed by the playground experts. In past publications focusing on design processes we presented timelines of three of the expert engineers: one with each of high, average and low quality scores (see reference [29] for more details). We selected these subjects as representative of the range of quality scores for the engineering experts.

Table 2: Engineering experts (E) and playground experts (P): Participant background. Reprinted by permission FIE[36]

| **Pseudonym** | **Evan (E1)** | **Earl (E2)** | **Eldon (E3)** | **Eric (E4)** | **Elizabeth (E5)** | **Phil (P1)** | **Perry (P2)** | **Patrick (P3)** | **Paul (P4)** |
|---|---|---|---|---|---|---|---|---|---|
| **Quality Score** | Low (0.430) | Average (0.548) | High (0.615) | High (0.623) | High (0.667) | High (0.610) | High (0.638) | High (0.738) | High (0.716) |
| **Current Title** | Product Design Engineer | Product Develop-ment Engineer | Core Tire Pressure Monitor-ing | Leader Engineer-ing: Passenger Systems | Consulting Engineer: System Protection | Playground Equipment Designer | Playscape Designer | Product Designer | Engineer-ing and Safety |
| **Years in Profession** | 30 | 13 | 18 | 17 | 19.5 | 42 | 14 | 20 | 5 |
| **Gender** | Male | Male | Male | Male | Female | Male | Male | Male | Male |
| **Age Range** | 51-60 | 41-50 | 31- 40 | 31-40 | 41-50 | 61-70 | 31- 40 | 41-50 | 31-40 |
| **Background and Training** | Electrical engr., Electronic systems integration, Control systems | Mechanical engr., Materials science, Physics | Systems engr., Electrical engr. | Mechanical engr. and design, many CAD classes | Electrical engr. | Art, Design & Child develop-ment | Undergrad-uate in Industrial design | BFA in Industrial design | Currently pursuing degree in Mechanical engr. |

As shown in Table 2 all four of the playground experts achieved high quality scores relative to the other participants. The final two engineering experts, we included, matched the playground experts for high quality scores and similarity in terms of design process codes in previous studies. The resulting sample of engineers had three high, one average and one low quality score. The engineering experts were screened to ensure that they did not have in-depth knowledge of playground design so that all engineering participants would not have domain experience. The playground designers were not screened for absence of engineering knowledge. This resulted in one subject, Paul (P4), having some engineering knowledge as he was about to finish a degree in mechanical engineering.

For a more complete picture of each participant we have also included a characterization of each playground expert or engineering expert. The sub-headings for each participant delineate particular aspects of our overarching findings. These include:

- Context: Background information that situates and provides a framework for moving through a design task. This analysis identified four context categories in the data: environmental, social, economic, and political.
- People: Consideration of the people-oriented codes, *actors* and *use* (Fig. 1). *Actors* relate to any human involved with the playground and *use* is how the playground equipment could or should be used.
- Knowledge: Personal knowledge stems from experiences within one's personal life and interests, whereas professional knowledge is gained from experiences in training, education, and professional practice.

This will allow for a fuller understanding of the experience of each of the participants, how each participant was able to problem solve, and the different areas of focus each participant held.

**Engineering Expert - Evan (E1)**

Evan was a male between the ages of 51-60 with a title of product design engineer. He had over 30 years in his profession of engineering, which focused on electrical engineering, electronic systems integration, and control systems. Evan focused on the equipment and how to correctly build the playground equipment. His questions were explicit and basic, as he appeared unsure of the exact path to take since playground design was not in his domain of expertise. This may have been one element in Evan achieving a low quality score.

*Context*

Evan spent the least amount of time considering context in the overall time he spent on the playground design. He seemed unconcerned with contextual issues and appeared to focus on completing the aspects of the project he knew best, which is discussed below.

*People*

Possibly as a result of this engineer's background and design workflow experience, Evan addressed the needs of his users through his many questions related to what the children would want on the playground and what equipment should be built. His questions revealed a desire to both design and implement the "correct" equipment, which would result in the children enjoying the playground.

> I guess the question is, do I focus myself to the equipment and assume somebody else is going to handle the safety of the area? […] Okay. Well, not knowing whether there's

> actually going to be enough time to consider all that, I think I will just restrict my activities to the equipment design.

*Knowledge*

An interesting aspect of this participant is that he held the most years of design experience of all the participants, but his project resulted in the lowest quality score. This may be due to his lack of domain experiences, as stated above, his questions were directed toward determining the exact approach to take, rather than making decisions based on his non-professional/personal knowledge of playgrounds. This may also be related to Evan's lack of assumptions, as it appeared he did not believe his knowledge was sufficient to make appropriate assumptions. For the one assumption he did make, he did so because he knew the standard from his own personal experience.

> [W]here I live it's – it's, uh – it has to be 24 inches into the ground. And I'm going to assume that that's a good number to accommodate our weather below the frost line, et cetera.

Evan's reluctance to make assumptions may have been why he restricted himself to equipment design, as this was something (as an engineer) he felt able to do safely and successfully. Thus, in recognizing what he did not know, he relied on his engineering background, not considering many factors relating to context, or pulling from his personal or professional knowledge which he may not have been seen as applicable.

**Engineering Expert - Earl (E2)**

Earl was a male between the ages of 41-50 who held a position as product development engineer. He had been in the engineering profession for 13 years with a background in mechanical engineering, materials science, and physics. This participant was very open and optimistic about the design and about the information he discovered throughout the process of designing the playground, and his project resulted in an average quality score.

*Context*

Earl's statements indicated that he made use of context based information about the environment 41 times in the three hours he was allotted to complete this task. His environmental focus tended to be based on a desire to situate environmental information in relationship to size and space constraints, along with the impact weather conditions would have on the playground. He used environmental conditions as the main indicator of what could and could not be in the playground.

> Okay! So I guess that you know the sketch of the corner lot and how the area would be very helpful, by knowing how much space you have to work in is always a good thing to know.
>
> ADMINISTRATOR: All right. I guess I have diagrams.

In line with Earl's focus on the environment, he made seven assumptions about the adequacy of the surrounding environment that then allowed him to concentrate on the design of the playground equipment and layout.

> Okay. Since I see stoplights and things around here and stop signs, I'm going to assume that we have proper crosswalk markings on the streets.

*People*

Earl used a great deal of personal knowledge in this process, thinking about what he had seen or experienced in terms of playground design to help him work through the task.

> Okay! So, you see our first thing is to kind of think about is what types of equipment one might want to put in there and see what things might work. Um, so, I guess what I will do is to start with those things, usual types of playground equipment and we will see what things we have here.

The result was Earl being confident in the path he was taking, assuming he was correct to work through designing the playground with what he had. Thus, he focused on completing a well-rounded and proper playground that would satisfy the community using the playground.

*Knowledge*

Earl was mostly focused on the environmental context and gathering of information. It is possible the amount of information he strove to gather, was because he knew, but did not explicitly say, that he was lacking knowledge in the area of this task. He was the engineer from our sample who seemed to understand the importance of contextual factors, with mst of these factors being related to his technical engineering goals. Thus because he stayed in line with his engineering goals, he also used a good deal of personal and professional knowledge, rather than making many assumptions, moving through the process fluidly.

**Engineering Expert - Eldon (E3)**

Eldon was a male between the ages of 31-40 who worked as a core tire pressure monitor. He had been in the field of engineering for 18 years, with a background in systems and electrical engineering. This engineering expert was highly focused on the overall procedure of getting something built and the general requirements that go along with such a process; specifically focused on budgetary constraints. Eldon appeared more concerned with framing and learning the guidelines associated with the project, so as to make sure he was fulfilling his role. This thoroughness also appeared to lend itself to the participant's high quality score.

*Context*

While it appeared Eldon was not concerned as much with social context, as that was not his role as an engineer, he did explicitly separate his area of expertise in order to get the project done for the community.

> I also need, uhm, guidelines for the American with Disabilities Act; don't know what that entails. Uhm, I also need to know where this is. Is this, uhm, a northern city that has snow, or is this a Southern city that's never going to see snow?

*Peopl*e

Although Eldon did not show a great amount of concern about social context overall, he was concerned about designing a safe playground for the client, and focused on completing the technical task of designing the playground.. Thus, he focused on actors and their use of the playground when it related to how the playground needed to be constructed, clearly delineating his role in the process.

> You know, when I'm constructing the beams to hold up surfaces, I need to know the weight-carrying capability, uhm, of those beams, how far to place the vertical supports,

uh, yeah. Now, this is where we're – we're struggling with to equate being an electrical engineer.

*Knowledge*

Seemingly due to his desire to fulfill his role as an engineer for this project, Eldon made 22 assumptions that fixated on getting the equipment built. He was also unsure about the quality or "correctness" of his assumptions and knowledge, asking questions and providing explanations that allowed him to feel confident in his choices.

> Okay. Seeing as I'm asked by the City to do this, am I to assume that it's zoned appropriately?
>
> ADMINISTRATOR: Uhm, I don't have any information on that, so you can do what you want with that.
>
> Okay. Well, what I'm getting at here is, you know, this is obviously a, uhm, probably zoned resident – or zoned – uhm, multi-purpose, those kinds of things.
>
> ADMINISTRATOR: I'm trying to get at that.
>
> Okay. What I'm trying to do is develop a, uh – uh, where I'm restricted from doing anything, to identify the restrictions, the constraints of the problem, in engineering vernacular. [Line 66]

**Engineering Expert - Eric (E4)**

Eric was a male between the ages 31-40 and had been in the profession for 17 years. He held the title of lead engineer in passenger systems and had a background in mechanical engineering with heavy use of CAD. This participant was very attentive to all details of his design, and made sure to list all resources and constraints before the project got going. He was also the only participant that suggested looking at other playgrounds for examples. His design obtained a high quality score. He moved through the process with a procedure in mind, which at the end seemed to stop him from finishing completely, as it appeared that he was used to completing multiple iterations or having more time to revise.

> So, what I usually probably would do at the very start is to read the whole thing again to make sure I haven't missed anything 'cause sometimes when I'm reading, I'm already thinking of things as I – when I should be reading more, I'm actually already thinking think of stuff that I need to be thinking of.

*Context*

While Eric did not consider the user often, as will be discussed below, he strove to ensure the user was taken care of as an important element to factor into the playground design. As a result, Eric focused on requirements as related to safety and what would be the "correct" equipment or organization of the playground for users with specific needs.

> I'm still struggling with this handicapped issue, whether I've got a good enough access for handicapped people to get into the park or if I want to add a gate over near the parking area where they'll be coming from. So, it'll be – they don't have to drive all the

> way around, go across parking lots or an entrance to a driveway/exit to get over to the gate.

*People*

Eric spent the least amount of time, of all the participants, thinking about people and their use of the playground. This seems to be the result of a rigid plan of action in his mind, which focused on implementation of specific equipment and playground elements and stressed finishing the task, rather than relating the context of playground space to the community that would use it.

*Knowledge*

Eric made six assumptions with the idea that making assumptions would help him to complete the calculations or smaller problem solving tasks. He seemed to be using basic professional knowledge necessary to design a structure. His assumptions were not related to social contextual issues as those were not the aspects of the problem on which he chose to focus.

> But I don't know that I have all the stuff here to size beams and swings and platforms and all that and size it properly.
>
> ADMINISTRATOR: You can choose to do whatever you – whichever way you like.
>
> I'll make some assumptions for that. But I would size some of this up. So, I don't think I'm going to have time to do a lot of that. So, okay. I'm also still struggling with just how big to make this. I'm trying to visualize the parking – or the playground area for the kids and what it should be.

**Engineering Expert - Elizabeth (E5)**

Elizabeth was our only female participant, with 19.5 years of experience, and was between the ages of 41-50. She worked as a consulting engineer in systems protection and had a background in electrical engineering. This engineering expert quickly moved into thinking about the context of the playground area. Her decisions seem to be based more on experiential knowledge, rather than playground building standards, but she moved very deliberately through the process, achieving a high quality score for her design. There was also a great deal of time spent thinking about how to implement all the components, rather than asking the administrator about the project. Overall, the participant appeared highly confident and was still confident when time was running low.

*Context*

Of the contextual factors Elizabeth considered, social context was the most prominent. This is most likely related to her high level of focus on people oriented factors and how participants would use the playground. She did not request a lot of contextual information, it seems, simply because she decided to work with what she immediately held in terms of knowledge and engineering design processes.

*People*

This participant made seven assumptions that completed needs for equipment design, situated her position in the project, and helped her make sure the playground was safe. Her assumptions regarding the social (community) context of the playground enabled her to bypass considerable information gathering and to avoid particular problems that might complicate her design process.

These were based in basic professional engineering knowledge or personal understanding of users.

> We're going to assume this is not the kind of area where – where people would vandalize or steal the equipment, or that there's someone who would – there's a place that it could be secured at night.

*Knowledge*

Again, many decisions for the playground seemed based on what Elizabeth had seen children using and she tried to find more creative alternatives rather than traditional playground equipment.

> So 1-year-olds need rather small equipment. They need some large motor activity, like climbing, sliding. So, let's say 1 to 4 year olds. They also seem to enjoy the sort of places where they can climb through things and play hide and seek.

As a result, her personal knowledge use was comparable to her use of professional knowledge.

Elizabeth was also forthright about her role in working through this task and delineated the extent of her expertise. This appeared to enable her to move further in the design process and may also relate to her high quality score.

> I'm assuming I can take this to my Civil friends and have them do calculations, right?
>
> ADMINISTRATOR: You can do whatever you want to.
>
> Okay. Because I'm not Civil.

**Playground Expert - Phil (P1)**

Phil was a playground equipment designer with 42 years of experience. He was male between the ages of 61-70 and had a background in art, design, and child development. Phil had a very strong conception of playground design as a whole and what was necessary in the design process and ended up with a high quality score. For example, he was adamant about not building the playground in the USA as requested, due to various legal issues, and thus he decided to design a community garden in the USA and to design the playground for a community in Mexico.

*Context*

This participant was focused on his past experiences and what he thought to be necessary for playground design. Thus, this participant directly questioned and changed many aspects of the given problem's context, in order to design a playground that suited his version of the task.

Stemming from his questions surrounding context, this participant made seven assumptions based on his professional knowledge and experiences working through the process of playground design.

> I think that works. Because these are native people, there are lots of craft skills; I'm going to assume that they can cut diagonals.

As a result, he was able to paint a picture of the context of the project in a way that would make the playground project successful.

*People*

Phil was somewhat scattered in his process, but focused on standards and professional knowledge, because he had the experience to assert the facts and what was needed. It was this experience that most likely lent to his high quality score. As a result of his experience, he was able to predict or ask about how the playground would be used by people in the surrounding community.

> This is not the first time that someone has come to me with this one, because it's just a heart breaker, because you know it's really needed. I mean you're right across the street from multifamily homes, and you're right next to the grocery store, which in this neighborhood is going to be a big problem, because that's where a lot of, shall we call it, transactions take place.

*Knowledge*

Phil showcased his knowledge and expertise by talking about the book he had published and also by explaining what was problematic about the design parameters and the community context as given.

> You know, I could just give you the book that I've written on this, build your own playground. It's got all these details in it. It's a pain in the butt to be redrawing it all.

> The reason that one would not as a designer do this, or as an engineer, would be that you are opening yourself up to extraordinary liability, and the design criteria set forth here are untenable. One could not build a quality, safe environment, given these restrictions.

**Playground Expert - Perry (P2)**

Perry was a 31-40 year old male with 14 years of experience as a playscape designer. He also had a background in industrial design. This participant was focused on situating the design problem in real life, and both acknowledged the constraints provided to him by the problem statement and administrator, as well as used his own knowledge of playground design to make necessary decisions and assumptions. Additionally, he produced detailed drawings to supplement his design decisions and stated that he made use of mediation and playing in his professional design work. Perry was focused on contextual factors, and also achieved a high quality score.

*Context*

This particular expert was extremely positive about the process, and focused primarily on context (more than all participants), the flow of the space, relationships, and the end-user to guide the use of the limited information he had available.

> I'm going to assume that this is a pet project of the Mayor himself, and usually projects like this you can get some support from the city, so I'd imagine that at least on the days of construction maybe they could help build it or bring heavy equipment.

*People*

Perry also focused a lot on people, relating to how actors within the community would interact with the overall playground space. He seemed to consider the people within the community in relation to the environmental, social, and political aspects of the community context. He spent more time situating the playground on the site rather than actually designing and planning the equipment implementation. Thus, his consideration of actors was more related to the community context than to how actors would use specific aspects of the playground.

*Knowledge*

Perry was quite serious about his role as a playscape designer, making note of how his professional knowledge applied in his work. Here the participant described what he did as a playscape designer.

> So I'm just thinking about what I do as a playscape designer, I mean the types of things that I – the projects that I work on and my own philosophy of city parks and green-space and thinking about just kind of the basic playground requests and feeling that a place like this needs more than just a few pieces of equipment in this big like flat place plopped here right on main roads, so just thinking about, yeah, all the possibilities, and, um, more than just the idea of a playground. [104]
>
> And I'm also making notes on each of these items of what my role is.

**Playground Expert - Patrick (P3)**

Patrick was a male product designer between the ages of 31-40 with 20 years in the profession and a background in industrial design. This participant moved through the playground design process in a straightforward manner also obtaining a high quality score. He seemed to have a very clear picture of what needed to get done, and in what order.

> And that should provide us a nice playground with lots of challenge for the whole age group that we think is going to be involved here, and have a nice sitting area for the parents and where they can watch their children and help keep them protected. And it should be a playground that is fairly low maintenance besides just keeping an eye on any wood that goes bad. But if we use all – all the wood needs to be pressure treated, then we should be okay.

*Context*

This participant made five assumptions based in professional knowledge of the best situation for the positioning and building of the equipment.

> Do you know whether the gate is opening in or out?
>
> ADMINISTRATOR: I don't. So you can make an assumption or do what you like.
>
> Or change the gates. [chuckling] All right. So what I'd like to do is let's assume that the gates open out, or we'll change them to opening out so that we aren't worried about swinging the gates against a raised surface.

*People*

Patrick also acknowledged in a variety of instances where he was making special considerations and affordances for his user group, ensuring the playground would meet their particular needs. This discussion of the user and future needs of the playground was raised in the midst of a process that seemed to be focused on materials and steps for getting the playground built.

*Knowledge*

Patrick covered a lot of ground in his design process, but he did not appear to be as as *flowy* and contextually connected as Perry in his way of thinking. Patrick also appeared to know what he wanted, and restricted his requests for social and environmental information because he already had knowledge of other areas. Possessing a clear vision for what needed to be done most likely contributed to his high quality score.

**Playground Expert - Paul (P4)**

Paul was pursuing a degree in mechanical engineering with a current position in engineering and safety. He was between the ages of 31-40 and had five years of experience in the profession of playground design. This participant focused on the parameters given to him in the problem statement and what he could discern from questions he asked the administrator. He appeared to treat the design problem much like a classroom exercise and only made assumptions when information was not available. Possibly as a result of his reading of the problem, he focused mainly on the construction of the playground with little attention paid to the surrounding community. This participant also had a high quality score.

*Context*

Paul considered the least amount of contextual factors overall for the playground experts, specifically spending the least amount of attention on social context of the playground experts as well. This appears to be a result of his focus on the building of the playground which is detailed further below.

*People*

This participant's discussion of how to design the playground was highly focused on how well the community would be able to implement and sustain the plans he created. Overall, this participant took a more straightforward and technically practical approach, but appeared to have a keen awareness of who his plans would be distributed to and how they would be used or implemented.

> And you're saying comply with ADA – so will be able to play also, so that means ground access, lots of ground access activities, not so much overhead events. (INAUDIBLE) not necessarily for all equipment to be accessible, but an effort should be made to allow handicap children to be able to use the playground. Okay. So here's what we're going to do: That's the first platform, and I think if I use any other platforms they should be the same so that they –when they are building this they can just slap the thing together.

*Knowledge*

Paul made seventeen assumptions that helped to move his design process forward. Nearly all of his assumptions dealt with the installation process, where he made assumptions about labor skill, material supply, and cost. Assumptions appear to be based in professional knowledge and made because he wanted to complete the design task.

> I guess we can use 1-by-8 scabbed together, if I don't want to assume that. I'm going to assume they have 2-by-8, and I'm going to assume it's twice this price. Because most hardware stores, even in LITTLE Rochester has 2-by-8.

Here the participant was making an assumption that would prevent the community members' lack of knowledge or expertise from complicating the design process.

> Okay. That's the platform. Now we're going to have a – let's get some net going off the back of this thing, and we will – as long as it doesn't have to comply to ASTM requirements, so I can be at liberty to do a few – few less higher skill things, huh?

Following, we describe our findings which present patterns among our participant groups as a whole.

## Findings

In addition to descriptive information about the participants, Table 3 presents the total amount of time that each participant spent designing the playground, and the time spent in each of the code categories (context, people, and knowledge). We have updated some analyses from this coding of the data that were previously published.[36] This paper should be considered the archival source for these analyses. Fig. 1 then presents how the participants distributed their time within each category as a percentage for each of the codes in that category.

### *Considering Context*

In this section we describe how the participants in this study chose to use their time with regard to the context. Context can be defined as background information that situates and provides a framework for moving through a design task. This analysis identified four context categories in the data: environmental, social, economic, and political.

All participants spent time considering context in varying amounts (see Table 3). It is interesting to note that the one who spent considerably more time on context issues was a playground expert, and the one who spent the least amount of time on context was an engineering expert. Paul (P4), the playground participant who spent the least amount of time considering context, had the fewest number of years in the field of playground design. Conversely, Evan (E1), the engineering expert with the most number of years in the profession, spent the least amount of time considering context. It is also interesting to note that in the code *social* in the context category as seen in Fig. 1, the four participants who spent the smallest percentage of time considering social issues were all engineering experts.

More interesting, may be the difference in type of context each participant considered. As demonstrated in Fig. 1, four of the five engineering experts considered environmental context more prominently than they considered *social*, *economic*, and *political* context. As Eldon (E3) stated, "Is this a northern city that has snow, or is this a southern city that's never going to see snow?" The one exception, Elizabeth (E5), who was the sole female participant in this study, considered social context more than any of the other context categories. In this statement, she addressed social context in how parents would be able to situate themselves in the playground; "Seems like it might be nice to include some shade, perhaps for the neighborhood gathering area or the moms – wow – the parents' area, where they can sit and watch the kids."

Table 3: Engineering experts (E) and playground experts (P): Participant scores and times

| **Pseudonym** | **Evan (E1)** | **Earl (E2)** | **Eldon (E3)** | **Eric (E4)** | **Elizabeth (E5)** | **Phil (P1)** | **Perry (P2)** | **Patrick (P3)** | **Paul (P4)** |
|---|---|---|---|---|---|---|---|---|---|
| **Quality Score** | Low (0.430) | Average (0.548) | High (0.615) | High (0.623) | High (0.667) | High (0.610) | High (0.638) | High (0.738) | High (0.716) |
| **Overall Times** | | | | | | | | | |
| **Total Time** | 02:25:29 | 03:01:16 | 02:28:36 | 03:01:08 | 02:50:15 | 02:43:49 | 02:58:37 | 02:56:26 | 02:56:48 |
| **Context** | 1:09 | 6:54 | 5:26 | 2:26 | 3:30 | 7:40 | 35:27 | 6:25 | 3:24 |
| **People** | 5:11 | 4:56 | 7:06 | 5:17 | 8:49 | 9:53 | 26:30 | 22:23 | 7:52 |
| **Knowledge** | 1:13 | 3:56 | 1:36 | 2:22 | 4:53 | 9:58 | 3:03 | 6:26 | 4:12 |

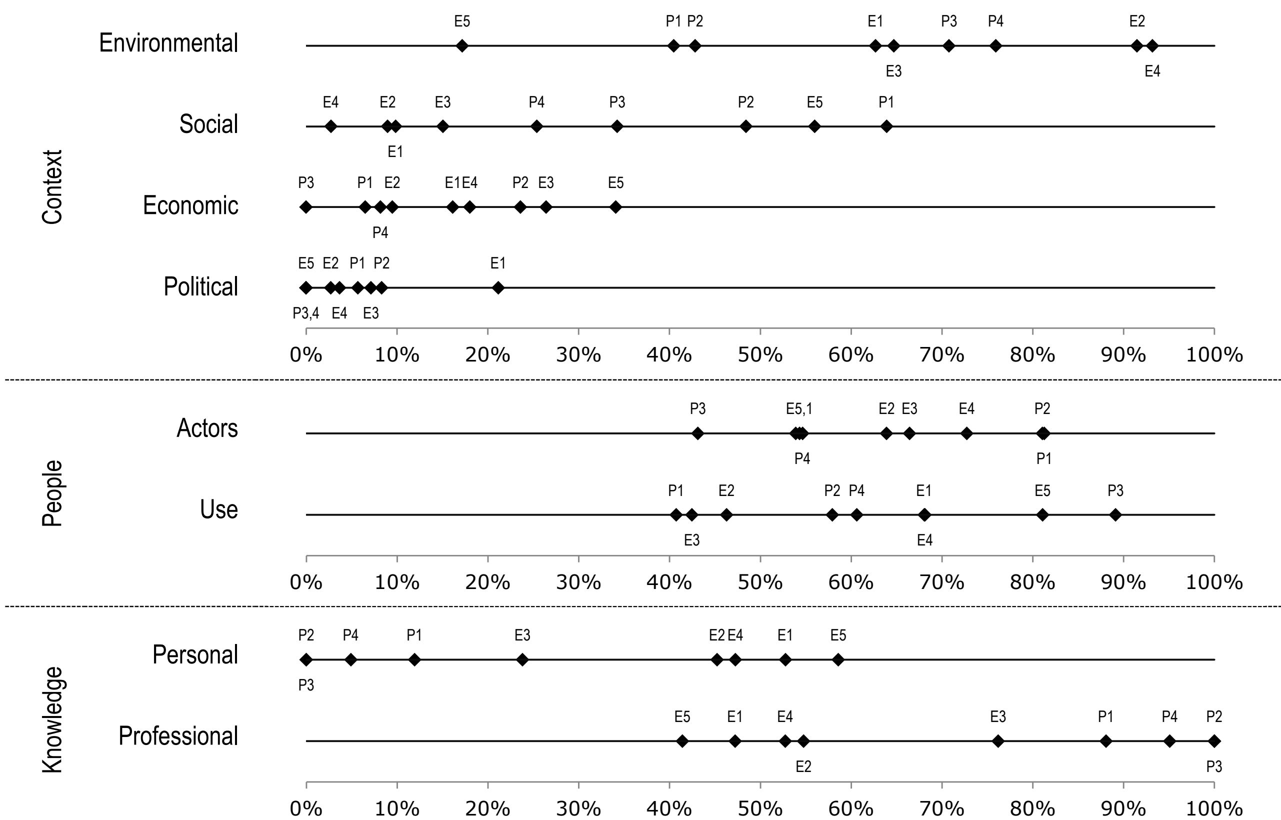


Figure 1: Allocation of time spent for each code within code category (shown as percent of total time in that category). E1=Evan, E2=Earl, E3=Eldon, E4=Eric, E5=Elizabeth, P1=Phil, P2=Perry, P3=Patrick, P4=Paul).

Within the overall percent of time participants spent on context, all the playground experts focused on social and environmental context for the bulk of their time. To illustrate, Perry (P2) stated,

> I'm trying to imagine that space, I'm imaging the families, and I'm trying to kind of feel the energy of the people and what their lives are like and how they know each other or don't know each other and trying to imagine standing in the middle of that space and thinking about the different seasons there and, um, how the sun moves through the space in the daytime and think about summer when it's hot, and maybe you need shade in places, and then thinking about wintertime and when they're plowing and wondering if they'll plow.

*Considering People*

Part of what makes noteworthy the consideration of social context by the playground experts is the fact that the engineering experts, while not as frequently as the playground experts, did consider the people-oriented codes, *actors* and *use* (Fig. 1). *Actors* relate to any human involved in building or utilizing the playground, and *use* is how the playground could or should be used. The transcripts show that the engineering experts considered people and playground use as concrete elements of specific problems in the playground task. In contrast the playground experts made broad connections to what they know about the actors and playground use. As an example, Eldon (E3) stated, "Picnic tables will be handicap-accessible meaning that the table-tops will extend farther than the benches to allow a wheelchair to be pushed up underneath". This passage was coded with *actors*, in reference to handicap users, and *use* for how the wheelchair would fit. The following excerpt illustrates how the playground expert Phil (P1) considered *actors*, *use*, and *social* context in a broader frame.

> ADMINISTRATOR: Let me see if I have anything that addresses that. What do you mean when you say "access"?
>
> Phil (P1): In other words, if this was a Jewish community center it would be very different from a local neighborhood. [Phil is given an information slip by the experiment administrator.] It says a lot, but it doesn't really give me a sense of whether or not we can restrict access.

Phil (P1) addressed *actors* and *use* by using the example of the Jewish community center, wherein that particular social setting provided opportunities to regulate and restrict how actors use the playground for purposes of safety. In attempting to make this playground safe, Phil noted potential issues of social context that would change the way in which the playground could or could not be enclosed.

Paul (P4), the playground expert with the engineering background, also spent a minimal amount of time considering actors, use, and social context together. As described previously and as seen in Fig. 1, four of the five engineering experts considered people related codes less than the playground experts. Again, Elizabeth (E5), as the sole female participant, spoke about people more often than the other engineering experts.

*Types of Knowledge Used*

Personal knowledge stems from experiences within one's personal life and interests, whereas professional knowledge is gained from experiences in training, education, and professional practice. While this is exploratory work with a small sample, the findings of the types of knowledge used by the engineering experts and the playground experts displayed in Fig. 1 are notable. Specifically, the engineering experts appear to be referencing their own personal backgrounds to make decisions about the playground design in lieu of professional knowledge within the domain of playground design. Different types of knowledge have also allowed participants to make assumptions that helped them in the process of design. Elizabeth (E5) stated:

> Bigger kids might enjoy, ah, like a jungle gym or some sort of climbing equipment, maybe digging equipment, um. I'm thinking about the places where my kids have had the most fun playing.

Elizabeth (E5) cemented her decision on equipment choice through personal knowledge. The playground experts, on the other hand, tended to make decisions based on their professional knowledge. For example Phil (P1) stated:

> Okay. Well, first I would question that the neighborhood does not have time or money to buy ready-made pieces of equipment, because my experience is that it actually takes considerably more time and money to construct a quality piece of playground equipment than a manufactured one. It's the same thing as if you were to – if I was to say the only chairs you can have in your house are from the local lumber yard. You could not possibly duplicate a chair reasonably.

The playground experts were largely focused on professional playground knowledge, whereas the engineers utilized both personal knowledge and professional engineering knowledge. The differences we found between the two participant groups may help to highlight a relationship between professional playground domain knowledge and the prominence of social context and people-oriented thinking that was displayed by the playground experts.

**Discussion**

This study suggests that domain experience provided playground experts with stronger broad contextual thinking as they moved through their design processes. Our research saw this in how the playground experts considered context (especially social-oriented factors) more often, and how actors' and playground use were addressed more holistically and in greater amounts. Additionally, the playground experts utilized more professional knowledge, whereas the engineering experts focused on professional engineering and personal playground knowledge to supplement the details given to them during the task. This potentially was a result of the engineers' focus on completing the technical side of the playground task (revealed by their emphasis on economic and political context). The knowledge the engineering experts utilized did not seem to further their consideration of broader contextual issues. Not only did the use of professional knowledge showcase that the playground experts, were domain experts, but it points toward a discussion on how greater experience in one's profession, or different educational experience, may provide a stronger base for thinking about social contextual factors and the potential for making broader connections.

It is an open question as to what these engineering experts would do if they had been asked to design something within their own professional domains. Potentially, if these experts had been asked to design something within their area of domain expertise we may have seen different individual processes. In addition to our overall findings, we are drawn to participant Paul (P4), a playground expert, and Elizabeth (E5), an engineering expert. Paul, a playground designer shifting to pursue a degree in mechanical engineering, was the playground participant who considered social context the least (Fig.1), along with the least amounts of the codes actors and use. Elizabeth's process was also interesting, she addressed social context in the greatest amount, with the highest numbers in actors and use of the engineering experts (Fig. 1). In other work, we have documented instances where female engineering students were more likely than their male counterparts to consider context while solving a design problem, potentially providing evidence that inclinations to think more broadly may be partially due to differences in life experiences.[19] Regardless, the focus of the playground experts, as domain experts, leads us to a discussion on how greater experience in one's profession may support broader considerations when approaching the needs of diverse and dynamic community-oriented engineering projects.

## Implications

"What engineers do, and are expected to do, includes much more than rational problem solving and constructing efficient means to reach desired, externally specified ends" stated Bucciarelli.[37] He further described the engineering discipline as object oriented and focused on concrete problem solving activities, generally making engineers unconcerned with issues outside their area of education. The overall findings from our study are consistent with these observations, leading to the following questions:

- Context: The playground experts in this study considered social context more than the engineering experts in the study, leading to the question, *"If domain experience may play a role in an individual's ability to consider social context factors, how can we help students understand and deepen this relationship as they start to develop expertise in their chosen domain?"*
- People: While both the playground and engineering experts in this study considered people in their design, the playground experts thought more holistically regarding actors and their use of the playground, leading to the question, *"If domain expertise may help people to situate a problem, how can we help students connect their experiences in a particular domain to the project at hand?"*
- Knowledge: The playground experts in this study predominantly used professional playground knowledge during their design process while the engineering experts used engineering professional knowledge, but tended to substitute personal knowledge for playground knowledge, leading to the question, *"How can we enable engineering students to recognize this substitution and reflect on the alignment of their personal experience with the needs of their users?"*

Alterations in curriculum and pedagogical processes may be a necessary step in answering these questions. As stated in the introduction to the paper, problem- or project- based learning could be powerful models for engaging engineers and helping them to enter the professional world with the tools and experience to be more comprehensive in utilizing contextual factors, and to be flexible and broad thinking in their work.[25, 38]

Beaty and Ball prescribed activities and experiences that allow individuals different modes of exploration resulting in expanded and more creative outcomes.[39] Moriarity argued for more experiences within engineering education for students to more quickly learn the industry standards as the base that will allow them to think more broadly and creatively.[40] In order for engineering students to contribute to the variety of communities that exist in our world, it is essential for engineering educators to support modes of thinking that are not only broad and contextually aware, but also creative in their approach to solving design problems. It is this inspired and imaginative thinking that will position engineers to make sense of new and dynamic challenges and to design successful projects for communities in need of particular and uncommon solutions.

We close with words from engineering students who participated in another study conducted by a subset of the authors on this paper.[41] In that study students in their junior year completed a brief engineering design task and then were asked: "Have you had any educational experiences that helped you do this activity?"

One student talked about "society classes" that taught them to mind the "needs of people," while "engineering classes" taught them "quality, quantity, those type of questions." A second student describes the integration of three sources of learning:

> *I could name several classes which influenced my thinking in terms of what were important design considerations. I think my STS [science, technology, and society] class made me think more in terms like ethical considerations and what the impact would be on the surrounding environment, and in ME [Mechanical Engineering] [class number], that, you know, taught me a lot about figuring out how are we going to build this thing, and where are we going to build it, and how are we going to put it all together, and I think that, um, basically the rest of it has just kind of been from everything, you know, a broader idea of how things go about being created.*

It is encouraging that these students are able to build on knowledge from multiple classes, use these insights to solve a design problem, and then articulate where they learned each perspective. By providing rich and varied learning experiences, from inside engineering classes, from other classes in the university and from co-curricular experiences, engineering students can graduate with the ability to incorporate issues of context and consideration of users of their designs.

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