It's Hard, But It's Worth It:

Teachers' and Students' Perceptions of the Benefits and Challenges of Design-Based Learning in a Middle School Classroom

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ABSTRACT

This research explores how design-based learning can be used as a pedagogical strategy in K-12 classrooms to foster students' 21st century skills in such areas as communication, collaboration, and critical thinking. The research aims to identify what students and teachers who participated in a design-based learning environment perceived to be the benefits and challenges of the project. The findings are used to suggest strategies that can be used to capitalize on the benefits and mitigate the challenges of the strategy.

This research employs a multiple case study methodology to investigate the unique perspectives of three audiences who participated in the study: (1) an eighth grade English teacher, (2) an eighth grade social studies teacher, and (3) fifty eighth grade students. It gives a detailed description of the results of post-implementation interviews during which participants reported on what they perceived to be the benefits and challenges of the project. The results of the interviews are utilized as the primary data source for the findings.

The study reveals that a majority of the participants perceived that students benefitted from the environment. They gained skills in communication and collaboration, developed the ability to empathize by exploring multiple perspectives, gained real-world experience that prepared them for their future by solving problems they identified in their immediate world, and gained knowledge and skills from a variety of disciplines. The teachers also benefitted from the environment in that they gained a new respect for their students' skills and abilities, explored and re-defined their own pedagogical philosophies, and improved their own design thinking skills.

While participants reported multiple benefits to the learning environment, they also acknowledged several challenges. Time was a challenge for everyone involved. Teachers perceived keeping students motivated when they faced ambiguity and assessing students to be a challenge. They also noted that administrative support for design-based learning is a challenge that must be overcome in order for wide-scale adoption to be realized. While students also identified many challenges to the environment, they consistently acknowledged that the challenging aspects – communication, collaboration, exploring multiple perspectives, managing real-world constraints, and critical thinking - were ultimately beneficial. The findings translate to an overarching message that design-based learning is hard, but it's worth it.

Acknowledgments

Nearly twenty years ago in 1994, I began a career as a public school teacher after having waited and worked to become one since I was eight years old. My first five years in the classroom taught me a great deal. They taught me that one month in your own, real-life classroom will teach you as much as four years of college. They taught me that the rewards of the job can sometimes seem few and far between; however, when they arrive, they are greater than any other reward you can receive. They taught me to always be prepared with Plan C, in case Plan A and Plan B don't work out. More than anything, though, they instilled in me a resolve to further my education so that I could somehow become more instrumental in promoting alternative teaching strategies that recognize and capitalize on the diverse range of knowledge, skills, and interests students bring to the classroom. My path to this higher education has been full of unexpected twists and turns, but I am grateful for all of the experiences I have had along the way and also certain that each of those led me to this place in some way. There are so many reasons to be thankful for where I am today.

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Chapter 1: Introduction

The State of Education Today

Modern society is a place of rapid change and increasing global connectedness. Ill-structured problems abound that require sophisticated problem-solving skills, knowledge across multiple domains, and the abilities to think critically and communicate effectively. Mastery of content knowledge in a given domain is no longer an accurate indicator of one's future success, yet modern classrooms still primarily mirror the traditional classroom model in which students are passive participants in the learning process (Nicaise et al., 2000; Robinson, 2010). A widespread call exists to transform modern classrooms into environments that foster the types of skills that students need to be successful in the future. In the words of Vockley (2007), "even if all students mastered core academic subjects, they still would be woefully under prepared to succeed in post secondary institutions and workplaces, which increasingly value people who can use their knowledge to communicate, collaborate, analyze, create, innovate, and solve problems" (p. 3). In order to foster such skills in our students, a "focus on innovation, creativity, critical thinking, problem solving, communication and collaboration is essential" (Carroll et al., 2010).

Even as long ago as the early 1960's, renown psychologist Jerome Bruner (1979) asserted that students need more time in the classroom discovering what is unknown rather than learning what is already known. Today, it is clear that policy makers, educators, politicians, and even corporate executives acknowledge the need for a change in the way we instill habits of learning in students. In the educational realm, new types of skill sets are increasingly prevalent components of local, state, and even national standards. At the national level, for example, the new common core standards for math and language arts include skills such as making inferences, summarizing, analyzing, integrating, planning, using analogical thinking, monitoring and evaluating progress, identifying relationships, conceptualizing, and reasoning (National Governors Association Center for Best Practices, Council of Chief State School Officers, 2010). In the realm of corporate America, an IBM report summarizing the findings from interviews with more than 1,700 CEOs around the world asserted that more than 75% of those interviewed named collaboration as a critical skill and the number one trait they seek in employees (IBM Corporation, 2012). Daniel Pink's 2005 best-selling book, *A Whole New Mind*, developed the widespread idea that alternative skills such as empathy, imagination, creativity, systemic thinking, and visualization are some of the most highly regarded skills sought by employers (Pink, 2005). Even the President of the United States has united with educators and policy makers who support transformative practices in education. In 2009 he urged the nation's governors to "develop standards and assessments that don't simply measure whether students can fill in a bubble on a test, but whether they possess 21st century skills like problem-solving and critical thinking and entrepreneurship and creativity" (Obama 2009). These examples demonstrate the need for students with skills that move beyond demonstrating mastery of rote knowledge.

While it is widely agreed that these skills – commonly referred to as 21^{st} century skills – are highly regarded in the real world outside the classroom, typical learning environments are still structured around a skill-and-drill model of pedagogy that was implemented during the industrial revolution to train future factory workers (Robinson, 2010). Milton Chen, Executive Director of the George Lucas Educational Foundation, noted

> the world has moved ahead in dramatic ways, but our schools remain caught in a web of educational thinking and systems that originated a century ago. The instructional model of the teacher and the textbook as the primary sources of

> knowledge, conveyed through lecturing, discussion, and reading, has proven astonishingly persistent (Barron & Darling-Hammond, 2008, p. 2).

While this pedagogical model may indeed be the predominant methodology in modern classrooms, there is also evidence of a changing structure in many classrooms. Tony Wagner, a former teacher and principal turned internationally acclaimed author, researcher, and lecturer, has noted that some schools have managed to break away from this outdated classroom model and develop modern learning environments that suit the needs of students today. He identified five distinct qualities of schools that have found a means to break away from the traditional culture of schooling and instead nurture students in an environment that fosters the skills of a new generation. Those qualities are collaboration, multidisciplinary learning, trial and error, creating, and intrinsic motivation (Wagner, 2012). An ever-expanding group of educators, policy-makers, and researchers alike are turning their focus toward design-based learning as a methodology that lends itself naturally to these qualities. Razzouk and Shute (2012) echoed the sentiments of many when they suggested that "design thinking is more than just a skill to be acquired and used in limited contexts. Rather, we view it as a way of thinking and being that can potentially enhance the epistemological and ontological nature of schooling" (p. 343). Similarly, according to Lind (2011),

> Sandy Speicher, head of the Design for Learning domain at IDEO, a global design consultancy, extols design education because its principles are often at the nexus of so called "21st-centurv skills." "The process of design is inherently a process of learning," Speicher says. "It's well documented that the jobs of the future require the skills to collaborate, to learn quickly, to be adaptable, creative, [and have a] facility with

> technology. Learning through the design process is a way to teach all those skills and also how to lead, follow, how to interpret and synthesize." (p.30).

The notion that design-based learning is an appropriate methodology for improving students' 21st century skills is one that is gaining increasing momentum in educational communities, and it is the notion that fueled the author's interest in the current investigation.

Design is arguably an activity practiced by nearly all people in their everyday lives. When one asks the question, "How can I change this situation to make it better?" and then attempts to develop and implement an answer to that question, that person is, in essence, designing. Glaser (1976) explained the prolific nature of design activity:

> The intellectual activity of design is involved not only in producing material artifacts as in engineering, but also in prescribing remedies for a sick patient, devising a sales plan for a company, constructing a new social welfare policy for a state, and designing a program of instruction for a school system (p. 5).

Cross (2006) posited that design is a culture or domain of learning and thinking that is as critical as science and the humanities. He referred to this culture as "Design with a capital D" and defined it as "'the collected experience of the material culture, and the collected body of experience, skill and understanding embodied in the arts of planning, inventing, making and doing" (p. 1). Cross explained that science, the humanities, and design each investigate unique phenomena, using unique methods, and have unique values. The sciences investigate the natural world using empirical methods, classification, and analysis. Objectivity, rationality, and truth are core values in the sciences. The humanities investigate the human experience using analogies, metaphor, and evaluation. The core values within this culture include subjectivity, imagination, and justice. Design, on the other hand, investigates the artificial world using modeling, patternformation, and synthesis. Designers value practicality, ingenuity, and appropriateness. Cross argued that design knowledge and *designerly ways of knowing* should be fostered in all educational curriculums alongside science and the humanities.

While it may seem that Cross has exalted the design domain to an extreme level in his argument for a third culture of learning, he is not alone in his perspective. In fact, many years before he articulated this notion, Archer (1979) also made the argument for design as a discipline in its own right. He stated, “human beings have an innate capacity for cognitive modelling, and its expression through sketching, drawing, construction, acting out and so on, that is fundamental to thought and reasoning as is the human capacity for language” (p. 3). More recently, in 1989 the United Kingdom acknowledged the importance of design as a unique discipline (National STEM Centre, 2011) and made *Design and Technology* a core component of the curriculum for all students (United Kingdom Department for Education, 2011). The general description of goals for students from ages seven to eleven, for example, states:

> During Key Stage 2 pupils work on their own and as part of a team on a range of designing and making activities. They think about what products are used for and the needs of the people who use them. They plan what has to be done and identify what works well and what could be improved in their own and other people's designs. They draw on knowledge and understanding from other areas of the curriculum and use computers in a range of ways.
>
> Teaching should ensure that 'knowledge and understanding' are applied when 'developing ideas', 'planning', 'making products' and 'evaluating' them. (United Kingdom Department for Education, 2011, para. 1).

Scholarly interest in the design domain and its methodologies dates back to the early 1960's, when London hosted the first ever "Conference on Design Methods." Since then, the study of design has grown continually (Cross, 2007). Research on design over the past several decades has revealed that the process of design is a type of complex, ill-structured problem solving (Jonassen, 2000), and the behaviors of good designers can be learned (Cross, 1982). Furthermore, design results in the production of some new thing that was previously unrealized. Inherent in this description is the notion of innovation. Creativity and innovation are at the core of the ISTE standards for learning effectively and living productively in our increasingly complex and interconnected society (ISTE, 2011), thus it is easy to see why design thinking is an increasingly popular subject (Cross, 2004) that is gaining recognition in educational circles. Interest in what Cross (2006) termed *designerly ways of knowing* has indeed gained increasing popularity over the past decade. Studies have been published to describe tools and strategies to enhance development of design thinking skills (Casakin & Goldschmidt, 1999; Casakin, 2011; Dorst & Cross 2001; Dixon, 2010; McDonnell, Lloyd, & Valkenburg, 2004), investigate the differences between novice and expert designers (Atman, Cardella, Turns, & Adams, 2005; Cross & Cross, 1998; Kavakli & Gero, 2002; Popovic, 2004), explore the characteristics of design thinking in different fields (Cross, Christiaans, & Dorst, 1994; Cross, 2004), and even investigate the increasingly predominant role of design in fields not typically associated with design (Lewis & Bonollo, 2002; Davis et al., 1997). Further, the recent surge in the notion that design activities foster 21st century skills such as collaboration, communication, critical thinking, and creativity (Gordon, 2011*)* and holistic thinking, empathy, imagination, and visualization (Lee & Breitenburg, 2010) has launched a movement to implement design in the classroom. As a result, studies investigating design-based learning environments have begun to emerge. Most of these studies, though, focus on university classrooms rather than K-12 classrooms. There is a need for additional research on design-based learning in pre-university education.

Research on and use of design in K-12 education has only recently begun to gain momentum in the United States. Part of the reason for this increased interest may be that educators who are searching for explanations of the achievement differences between students in the U.S. and other countries have noticed that design has become a requisite part of the curriculum not only in the United Kingdom, as mentioned previously, but also in many of the countries that score higher than the U.S. in comparative rankings. For example, according to the 2009 Program for International Student Assessment (PISA), U.S. students rank 23rd out of 66 countries on the science literacy scale and 33rd out of 66 countries on the math literacy scale (Organisation for Economic Co-operation and Development, 2010). On a similarly bleak note, the New York Hall of Science report in 2012 revealed that fewer than 15 percent of U.S. undergraduates received their degrees in science or engineering compared with 50 percent in China and 67 percent in Singapore, and in 2009, 51 percent of U.S. patents were awarded to non-U.S. companies (New York Hall of Science, 2012). Interestingly, China has created over 1,000 new design schools in the past decade, and Asian countries other than China such as Korea, Singapore, and Japan also make design education part of national policy (Lee and Breitenburg, 2010).

In the United States, an emphasis on the importance of design is not a nationwide focus as in these other countries. Instead, pockets of support for design are evident in more locally focused settings. For example, the Design and Architecture Senior High (DASH) opened in Miami, Florida in 1990 and is ranked as the top magnet school in the nation (Ellen, 2008). Ellen (2008) explains that the school's population mirrors the diversity of Miami's population in general, yet even with a large percentage of minority students the school's graduation and college enrollment rates are both 100%. She argues that much of this success can be attributed to the design curriculum: "The consistent application of project presentations for the purpose of critique develops critical thinking skills, constructive verbal interaction and personal confidence" (p. 39). The Charter High School for Architecture and Design (CHAD) opened its doors in Philadelphia in 1999 with a focus on "using architecture and design as a vehicle for a new type of teaching and learning" (Lind, 2011, p. 30). The school has become a model that other schools are using to restructure their curriculum to include more design instruction (Lind, 2011). Manhattan opened the doors to New Design High in 2003, and the Williamsburg High School for Architecture and Design opened its doors in Brooklyn in 2004. While each of these schools is an example of the promise for the future of design as a central concept in pre-university education, they also represent a systemic commitment on the part of each of these schools to incorporate design thinking in the classroom. The resources and support needed to implement such a pedagogical strategy are available because the entire school is focused on the same mission.

But what about educators who want to use design-based learning as an instructional strategy yet have no access to such support? As interest in design strengthens, more and more educators find themselves as members of this category. As a result, models of the design process for K-12 environments are beginning to emerge. These models are set forth by educational researchers as well as notable design schools and companies such as the Hasso Plattner Institute of Design at Stanford University (aka d.School), the Public Broadcasting Service (PBS) Design Squad web site, and the professional design company IDEO. Research using each of these models in the classroom is beginning to surface, but none outside the realm of the researchers who devised the models. If support for design-based learning in the classroom is to grow, it is important to build a larger inventory of research that documents the benefits and challenges of design as a pedagogy. Further, although the different models all offer practical and useful resources for teachers to use in the classroom, little evidence exists to document students' and teachers' perceptions of the experience. Since they are the ultimate target audience for design-based pedagogy, and since the process of design can be messy, even chaotic-seeming, in a classroom of students with little experience working through ill-structured problems independently, documenting students' and teachers' experience within a design-based learning environment will be an important contribution to the literature base. The etic perspective gained through meaningful qualitative research will serve others who set out to implement future design-based learning environments. It is important for educators to understand the nature of the environment and determine how to incorporate such a pedagogical strategy within their unique organizational constraints and personal teaching philosophy.

One of the goals of instructional design is to identify appropriate learning environments for specified learning goals. In other words, instructional designers strive to develop optimal strategies for optimal learning. To explore the benefits and challenges of design-based learning in a K-12 classroom is a useful endeavor for any researcher whose aim is to better understand and inform the field of instructional design with regard to design-based learning as a pedagogy. According to Seels and Glasgow (1998), one type of relevant and meaningful research in the field of instructional design is the study of the implementation phase of designed instruction.

The research reported herein is a case study of students' and teachers' perceptions of the benefits and challenges of design-based learning as implemented in an eighth grade classroom. The researcher and two teachers utilized a design-based learning methodology with eighth grade students over the course of 18 weeks. After implementation, the researcher collected data about the students' and teachers' perceptions of the benefits and challenges of the learning environment through post-implementation interviews. The researcher also collected artifacts of student work, reflections from students and teachers, researcher reflections, observational field notes, and audio and video recordings of activities to be used as secondary data to support or refute the information derived from the interview data. The design-based learning environment in this context is defined as one in which students work in teams to build a designed artifact that represents the solution to a real-world problem they personally identified. This comprehensive case study investigation will help provide a vivid description of students' and teachers' perceptions of the benefits and challenges of design-based learning in the classroom. The central research question is as follows:

- What are students' and teachers' perceptions of the benefits and challenges of design-based learning?

This research is of value in several ways. First, it will add to the knowledge base about design-based learning in K-12 settings. Little such research currently exists. Further, much of the research that documents implementation of design-based learning in pre-university environments has been conducted by the professionals who created the models. The researcher in the current investigation had no part in devising the model of design-based learning used in this study, so the results will be more typical of what others with no connection to the model or with little design knowledge may experience. Those with limited prior exposure to design-based learning will also benefit from a description of teachers' and students' perceptions of the benefits and challenges of the implementation. Such description will help them generalize the process for their own target audience and build a vision of how to implement a similar strategy in their own instructional plan. Lastly, through a detailed investigation, the results will help instructional designers and educators plan design-based learning environments that capitalize on the benefits and mitigate the challenges identified.

Chapter 2: Review of Literature

The current investigation was driven by an original interest in understanding the process of design as it relates to the task of instructional design. The review of literature that informed this research necessarily began with a comprehensive investigation of the research related to the design domain. Rowland (1993) suggested that instructional designers who strive to develop a deeper understanding of the design process may discover a new perspective on the complex nature of real-world instructional design. He argued that instructional design is a subset of design and highlighted how the processes of instructional designers match the processes common to all forms of design. He described several defining characteristics of design and related each to the tasks of instructional designers. Table 1 summarizes Rowland's assertions.

Design Characteristic	Application in Instructional Design
Design is carried out for the purpose of creating some new thing of practical utility	Instructional design is directed toward the practical purpose of learning, i.e., the designer seeks to create new instructional materials or systems in which students learn.
Design involves converting information in the form of requirements into information in the form of specifications	Instructional designers attempt to develop an understanding of the *conditions* and the *outcomes* of instruction in order to develop *methods* for instruction.
Design processes vary depending upon the nature of the thing to be designed	In instructional design, different tools and techniques may be employed, depending on whether a new system or a performance improvement is involved or whether a single piece of instructional material or an entire curriculum is to be created.
Design is a social process	In order to determine requirements and create effective methods, the designer must work with the clients and sponsors of projects, subject-matter experts, producers and actors, teachers and learners.
Design is ill-defined problem solving	Expert instructional designers treat problems as ill-defined and explore multiple potential solutions early in the design process
In designing, problem understanding and problem solving may be simultaneous or sequential processes.	Effort to understand an instructional problem (or opportunity for learning) may precede consideration of methods, or methods may be considered simultaneously.
Designing involves technical skills and creativity, rational and intuitive	Instructional design is described both as a logical, rational and systematic process, as in the case of

thought processes	prescriptive models of instructional design (e.g., Dick & Carey, 1990). It is also described as a creative process in which designing is driven by the recognition of opportunities and is carried out in iterative cycles (e.g., Banathy, 1987; Earl, 1987).

Table 1: Parallels Between Design and Instructional Design
(compiled from information in Rowland, 1993)

The researcher explored these parallels in an attempt to understand not only how instructional designers might become better designers, in general, but also how to foster the complex skills utilized in design (Rowland, 1993) in educational settings for K-12 students. The information presented in this chapter provides an overview of the research on design from several vantage points. It begins with an exploration of the nature of design in general by describing common features of all design environments and behaviors commonly observed in experienced designers. Next, it explores how design is utilized as a pedagogical strategy. This exploration of the pedagogical underpinnings of design-based learning is followed by a description of what research has shown to be the benefits and challenges of design-based learning in multiple design domains. The review includes next a comparison of several different models of design that have been developed for use in K-12 classrooms. The chapter concludes with an exploration of what current research has to say about why design-based learning may be an appropriate strategy to address the gaps in current educational environments as described in the introduction.

Characteristics of Design

Richard Buchanan, former Director of The School of Design at Carnegie Mellon University, described design in the following way:

> Design does not have a subject matter in the traditional sense of other disciplines and fields of learning… Design is the human power of conceiving, planning, and making

> products that serve human beings in the accomplishment of their individual and collective purposes. (Margolin, 2010, p. 71)

Buchanan's statement illustrates the elusive nature of a unified vision of what constitutes design. Because design is utilized by practitioners in a variety of fields and because its products are subjective, design means different things to different people. There are, however, several characteristics of design that are commonly agreed upon. The following sections describe each of these in more detail.

Ill-structured problem solving.

Perhaps the most broadly described notion of design is that it is a type of problem solving. Problem solving is an activity that requires sophisticated cognitive skills, and it is widely described as a universally important learning goal (Archer, 1979). Not all problem solving, though, can be characterized as design. Problems differ in a variety of ways including the type of learning activity, inputs, criteria for success, context, structuredness, and abstractness (Archer, 1979). Archer identified eleven different categories of problems according to these characteristics. These categories each fall along a continuum of complexity. As problems increase in complexity, their structure decreases. At the lowest level, logical problems such as arithmetic problems are well-structured. Design problems, on the other hand, are one step below the highest level of complexity and are characterized as ill-structured problems. Jonassen (1997) also explained different types of problems. He argued that problems can be grouped into three main categories: puzzle problems, well-structured problems, and ill-structured problems. Puzzle problems are "decontextualized problems that are designed to manifest reasoning and thinking processes" (p. 67). All of the necessary elements for a solution to a puzzle problem are either known or can be known, and there is a single solution to the problem. Well-structured problems, according to Jonassen, are similar to puzzle problems. The initial problem includes all of the elements needed to solve the problem, the goal state is known, and there is a specific set of processes that can be utilized to solve the problem. They differ from puzzle problems in that they are domain-specific and require skills that can only be transferred to other similar problems. The third type of problems, ill-structured problems, are characterized by a incomplete specification of the problem, multiple potential solutions, and a need for knowledge from multiple domains. As Cross (2006) described them, “they are not problems for which all the necessary information is, or ever can be, available to the problem solver” (p. 7). Simon (1973) further characterized ill-defined problems as having (1) no criteria for measuring the correctness of a solution, (2) an incomplete specification of the problem space, (3) potentially relevant knowledge from multiple domains.

Ill-structured problems have many characteristics that are consistently described throughout the literature (Archer, 1979; Cross, 2006; Fortus et al., 2005; Goel & Pirolli, 1992; Jonassen, 2000; Nelson, 2003; Simon, 1973). First, they contain an insufficient or incomplete statement of the problem. In other words, the problem, as given, does not contain enough information for the problem solver to reach a solution. Such problems also have multiple potential solutions. There is no single correct answer to an ill-structured problem and no pre-determined path from problem to solution. Ill-structured problems are also problems that require knowledge from multiple domains. Goel and Pirolli (1992) noted that “the kinds of knowledge that may enter into a design solution are practically limitless” (p. 396). Further, the criteria for evaluating solutions to ill-structured problems can be vague and value-based, so an answer that might seem appropriate or correct in the eyes of one evaluator might not be deemed as such in the eyes of a different evaluator. Given the ambiguous nature of these types of problems, the problem solver is often faced with making judgments or imposing personal beliefs on the problem to derive a solution. It is the nature of ill-defined problems that supports the second notion of design as a solution-focused and constructive mode of thinking.

Solution-focused thinking.

Another universal feature of design is that it is a solution-focused method of problem solving (Cross, 2006; Cross, Christiaans & Dorst, 1994). This is also called a top-down or breadth-first strategy of problem solving (Perez, Johnson, & Emery, 1995). Solution-focused thinking refers to the practice of generating a variety of potential solutions to the problem early on in the design process and then evaluating the solutions until a final product is reached through a process of elimination (Cross, 2006). This strategy has been repeatedly documented in empirical studies of design behavior (Casakin & Goldschmidt, 1999; Dorst & Cross, 2001; Atman et al., 2005). In fields where problems are well defined, such as math and physics, problem solvers analyze the problem environment to determine what rules are guiding the environment. Their goal is to learn the nature of what already exists. Designers, on the other hand, search for a solution that does not yet exist (Rowland, 1993).

Constructive thinking.

Design is also a constructive act (Cross, 2006). In well-structured problem solving environments, thinking is characterized by pattern *recognition*. Problem solvers break apart the components of the problem to find the existing patterns within. Designers, on the other hand, use what Cross referred to as pattern *synthesis*. They search to build interconnections within the problem space that help them develop frameworks for their solution. Constructive thinking also encompasses the notion that designers build things that do not yet exist. Rowland (1991) echoed this constructive view of design when he described design as “a process engaged in to create something new of practical utility” (p. 10).

Iteration.

Another generally agreed upon feature of design is that it is an iterative, rather than linear, process (Nelson, 2003; Roozenburg & Cross, 1991). Iteration, according to Neeley (2007) is “a critical means by which ideas are developed, tested, and refined” (p. 87). Designers move back and forth between understanding the problem and building a solution frequently during the design process. The knowledge relevant to the problem changes within each cycle, and the designer’s understanding of the problem deepens as the process unfolds (Goel & Pirolli, 1992). In this way, the problem and solution both evolve continually during design (Dorst & Cross, 2001). It is important to note that this deepening understanding and use of different knowledge is a unique feature of design problem solving.

Goel and Pirolli (1992) explained that problem solvers working on well-defined problems might also work toward a solution through an iterative process, but only when their first strategy leads to an incorrect result. In that situation, as they begin to cycle through the problem solving phases again, the only thing they know is that the first solution was incorrect. They have not gained any knowledge that can help them solve the problem more successfully, because all of the information needed to solve the problem is available from the start. Design problems, though, are quite different. As the designer analyzes the problem and evaluates potential solutions, the knowledge that is gained and/or activated can provide insights that refine the designer’s original conception of the problem. In this way, designers continually redefine the problem as they develop and assess their potential solutions.

These characteristics of design – ill-structured problem solving, solution-focused thinking, constructive thinking, and iteration – are common to all types of design. In addition, there appear to be a set of common factors that guide designers' behaviors and decision making as they work through the design process using these characteristic behaviors.

Common Guiding Factors

Goel and Pirolli (1992) noted that another commonality among all design environments is that designers use the same guiding factors as they work through the design process. These guiding factors are people, purpose, behaviors, function, structure, and resources. The people for whom the design is developed – that is, those who will use the designed product – guide the designer's decisions. An audience of CEOs and an audience of six-year-olds would obviously guide the designer to make different decisions when designing a shoe, for example. Secondly, the *purpose* of that audience is important. CEOs might want shoes that are not only professional looking but also comfortable. A child's shoe, on the other hand, might call for the designer to consider safety as well as how easily the shoe can be put on and taken off. Designers also think about what *behaviors* will signify a satisfactory design. For the CEO's shoe, that behavior might be a shoe that hides scuffmarks well or it might be a shoe that provides optimal arch support. For the child's shoe, perhaps the behavior could be described as a shoe that does not wear out before the child outgrows it or a shoe that a six-year-old can put on without help. The *functionality* requirements mediate the considerations of *people*, *purpose*, and *behavior* to the ultimate structure of the design. Finally, *resources* such as time, cost, and materials impact the decisions designers make.

In summary, design is an iterative process used to solve ill-structured problems through solution-focused thinking that aims to generate something new and useful. As designers work to build solutions to design challenges, they make decisions using a common set of guiding factors that constrain the solution options. This general view applies to design in all contexts. There is also consensus about the general features of the design environment, which is the focus of the following section.

Features of the Design Process

The messy and exploratory design process is of course conducted in a literal physical space, but the design space also refers to a conceptual, cognitive space through which designers navigate as they work to understand and devise a meaningful solution to a problem. Neeley (2007) described design as a process that happens within two main "spaces" referred to as the problem space and the solution space. He stated, "The navigation of ill-defined problem spaces and exploration of ambiguous solution spaces are the defining traits of design activity and it is these traits, when successfully executed, that beget innovation" (p. 10). There are a multitude of models to represent designers' work in this space. Cross (2008) presents several of these models and then suggests a general symmetrical model of the problem/solution space similar to Figure 1.

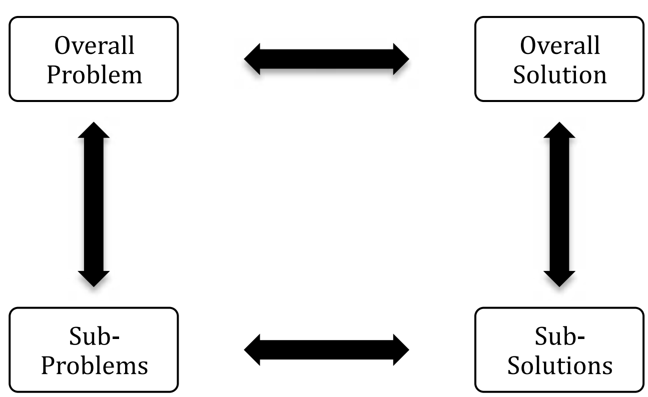

Figure 1: Model of Design Process Spaces (Cross, 2008). Reprinted with permission.

Within these spaces, designers identify and analyze the problem and suggest and evaluate potential solutions to the problem. The design process is iterative, and the designer's understanding of the problem and the relevant knowledge needed to solve the problem deepens through the cyclical progression through these stages of design.

The iterative design process includes several distinct phases within the problem and solution spaces. Nelson (2003) characterized these phases as naming, framing, moving and reflecting. Naming involves identifying the salient features of the problem. Once these salient features are laid out, the designer enters into the framing phase, during which the boundaries of the problem are defined. In other words, the designer identifies which features of the problem to focus on and which features are not relevant to the goal. Work conducted during these two phases of problem solving is considered work within in the problem space. Any actions that further an understanding of the problem and its limitations are part of the problem space. Once the problem has been identified and properly framed, Nelson (2003) explained that the designer progresses to the moving phase. This involves taking steps to develop a solution to the problem or a subset of the problem. This phase of design marks a designer's work in the solution space. The solution space involves any work that the designer does toward conceptualizing or developing a solution to the problem. The final phase of this iterative design cycle, reflecting, involves evaluating the preliminary design within the established framework of the problem.

Goel and Pirolli (1992) also described design as a four-stage process, but they instead identified the four stages as analysis, indentifying interconnections, solution of subproblems, and synthesis. While their description of the design process omits the concept of reflection, the synthesis stage implicitly involves not only combining the individual subproblem solutions into a final solution but also evaluating that solution's value through a reflective process.

Cross (2008) suggested seven distinct stages of the design process but noted that these are not necessarily all requisite stages in every design space. The stages include clarifying objectives, establishing functions, setting requirements, determining characteristics, generating alternatives, evaluating alternatives, and improving details. Cross placed these stages within his symmetrical model of the problem/solution space as shown in Figure 2.

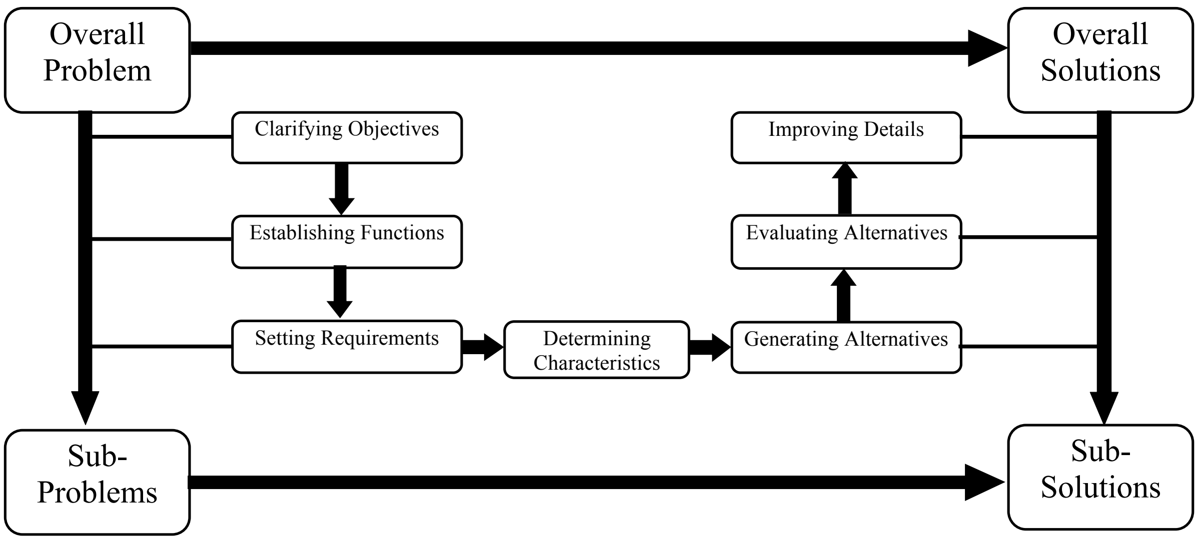

Figure 2: Cross' Seven Stages of the Design Process (Cross, 2008). Reprinted with permission.

This model effectively visualizes the processes that occur within the problem space and the solution space and demonstrates the iterative nature of the design process. In order to better understand the cognition of designers, Cross and others have also investigated designers' thought processes that dominate behavior within these phases.

Cognitive Aspects of Design

Extensive research has been conducted on the cognitive nature of design. Such investigations are most frequently conducted using a verbal protocol analysis in which designers think aloud while they solve a problem (Ericsson & Smith, 1991). Their thinking protocol is then coded and categorized to find patterns and broad categories of behavior that can best characterize their self-described cognitive activity. Several notions about design thinking have been forwarded through research such as this. These characteristics might also be considered a summary of what is meant by the term ‘design thinking.’

Problem structuring.

First, as already described, designers spend a significant amount of time structuring the problem (Atman et al., 1999; Ball et al., 2004; Chi, Feltovich, & Glaser, 1981; Cross, 2006; Goel & Pirolli, 1992). Structuring involves breaking down the problem into component parts and looking for connections among those parts. The connections, though, are not inherent within the problem space. This is where the designer’s cognition plays a role. Designers use their prior knowledge and their experience to formulate those connections. They restructure the problem in way that aligns with their existing knowledge (Goel & Pirolli, 1992, Perez et al., 1995). Experienced, skilled designers are said to have highly complex and organized cognitive schemata that allow them to frame the problem successfully. Novice designers, on the other hand tend to rely on the surface features of the problem since they have little experience and prior knowledge to build on (Lawson, 2004). Cross and Cross (1998) called these guiding principles and observed that highly skilled designers all demonstrate the use of such guiding principles. Others have called these principles “gambits” (Lawson, 2004), “rules of thumb” (Casakin & Goldschmidt, 1999; Kirschner, Carr, Sloep, & van Merrienboer, 2002), and a “bag of tricks” (Lawson, 2004).

Co-evolution of problem and solution.

As designers develop their understanding of the problem, they also begin to generate ideas for a solution. These ideas begin to form before they even fully understand the problem (Goel & Pirolli, 1992). This is typical design behavior that some label as opportunistic design behavior (Guindon, 1990). As soon as they identify a meaningful connection that can help them generate a solution, they capitalize on that connection, begin building a solution and remain attached to this original solution idea as long as possible. Cross (2006) referred to this as a designer's *fixation*. Even as they restructure the problem continually through iterative passes through the problem space and solution space, they strive to maintain their original solution idea and modify it to make it fit within the task constraints. Researchers also call this co-evolution of the problem and solution space and point out that it is a salient characteristic of designers' behavior (Dorst & Cross, 2001; Goel & Pirolli, 1992).

Sketching and modeling.

Cross (2006) pointed out that all designers use sketching or some other form of physical modeling. He described how industrial designers, architectural designers, and even engineering designers utilize sketching not only as a communication aid to convey their solution ideas to others but also as a thinking and reasoning aid. First, sketching helps designers "handle different levels of abstraction simultaneously" (p. 37) as they simultaneously investigate the problem and solution. Sketches also "enable identification and recall of relevant knowledge" (p. 37). As designers build iterative sketches of their solution ideas, they incorporate what they've learned about the information that is relevant to a solution. Design sketches also facilitate designers' ability to structure the problem more clearly through iterative attempts at a solution. As they generate sketches, designers explore the problem space and solution space to generate sketches that include not only drawings but also numbers, symbols, and other text that help them create a "matching problem-solution pair" (p. 37). Finally, sketching facilitates the designer's ability to recognize the emerging features of the solution. While such a behavior may seem to be an overtly physical rather than cognitive behavior, Cross suggested that sketching and modeling has several functions that are cognitively focused. Designers use sketches not only to derive ideas for the look of a product, but also as a way to help them make vertical and lateral transitions in the solution space. Vertical transitions are linear, logical progressions in a design concept. Lateral transitions are creative shifts in the design concept that lead to more innovative designs. These transitions are an abstract, qualitative measure that designers use to assess their progress in the solution space.

Codes.

Cross (2006) also described how designers use *codes* while working on a design task. A code is an abstract concept that represents a designer's ability to transform some conceptual need or idea into a physical form. He suggested that this process lies at the core of design and is still poorly understood: "what designers know about their own problem-solving processes remains largely tacit knowledge – i.e. they know it in the same way that a skilled person 'knows' how to perform that skill" (p. 9). What we do know is that these codes differ from one domain to the next and that they help the designer make connections between what is known in the problem space and what becomes in the solution space. Lawson (2004) similarly referred to a unique language that designers speak amongst themselves. In this language of design, according to Lawson's description, a single phrase can point to an enormous amount of information. He referred to these chunks of information as designers' schemata and described how architects use the term *belvedere* to mean something much more than a viewing tower. "For them, it was not a matter of a building typology at all but rather a whole series of devices for organizing space vertically in order to afford dramatic views that helped building users to build mental maps of their surroundings" (p. 446).

Design-Based Learning in the Classroom

The information presented thus far has demonstrated that designers exhibit similar behaviors no matter what the domain and that there are typical phases or stages of design to which all designers attend. What remains to be seen is what type of problems, specifically, designers tackle. While it is established that those problems are ill-structured, the reader has no frame of reference for understanding what types of challenges to present in specific learning environments to foster design thinking. The following sections describe some typical design challenges in different domains. All of these challenges are ones that were used by researchers conducting formal investigations into the nature of the design process, design thinking, and/or design expertise.

Engineering design.

Cross (1982) described one engineering designer's challenge of making a Formula One racecar lighter in weight. The designer's ultimate, award-winning solution did not modify the car at all but rather utilized the pit that had previously only been used for emergency stops. Instead of filling the car's gas tank completely, the designer conceived that the car could run faster with only half a tank of gas and that the time spent filling it more often would be less than the time lost due to the weight of the extra fuel. Dixon (2010) presented engineers with a challenge to modify the design of an existing motorcycle so that it could be reliably used as a means of transportation for two passengers through a rugged, mountainous, often wet terrain. He further constrained the challenge by stating that the motorcycle must be equipped with additional cargo capacity, have a non-metallic rack that is sturdy enough to withstand the rugged conditions, have enough horsepower to climb at a 30 degree angle with two passengers, and contain a device to prevent helmet theft. Finally, Atman, Chimka, Bursie, and Nachtmann (2005) challenged engineering designers to craft a device no larger than 1m x 1m x 1m that could launch a ping pong ball accurately at a target 5 meters away. Each of these engineering design challenges demonstrates the structural constraints typical of problems in this sector of design.

Architectural design.

Casakin (2011) presented students of architecture with a challenge to design “a compound of approximately eight dwellings of 100 square meters each, in a decayed area of Tel Aviv” (p. 34). The design challenge constraints forced the architects to consider how their solution could be integrated in the existing space, offer public spaces, and improve the look of the existing area. Casakin (2004) conducted research using design challenges that are common to students of architecture. First, he challenged the designers to conceive of a single-story prison that contained 80 cells, each of which having one exterior wall. The challenge was further constrained in that the prison needed to house facilities for the guards and allow the guards to control all prisoners effectively. The second challenge asked designers to design a tower 16 meters in height with a viewing terrace at the top. The challenge constrained terrace size to 30 square meters. Further, the terrace needed to have two parts: the first part should have maximum contact with the ground while the second should have minimum contact. Finally, Casakin’s third challenge was much like the challenge described above in his 2011 study. He asked students to “design and organize a set of 20 small, repetitive, and compact dwelling units” (p. 6). The constraints specified that the design must strive for minimal exposure to the exterior, be single story, and use principles of orthogonal geometry. Again, each of these examples demonstrate a common theme within architectural design challenges: the design of structures.

Industrial design.

McDonnell, Lloyd, and Valkenburg (2004) challenged industrial designers to design packaging for a beer bottle and a glass for an upcoming promotion. The challenge constraints specified that the packaging should be easy to open and close and that it should be durable enough to not only hold the weight of but also protect the contents. Dorst and Cross (2001) challenged their subjects to design a new waste disposal system for new trains in the Netherlands. Lewis and Bonollo (2002) reported a variety of real-world design challenges between their students and local clients that they evaluated students' performance on: "car roof rack, electric guitar, park chair and bench, portable gas barbecue, supermarket shelving, self-propelled garden sprinkler, surgical retractor, backpack satchel" (p. 387). Finally, Ho (2001) studied industrial designers as they conceptualized "a communication facility with an answering function" (p. 30). Along with the general design challenge, participants in the study were given two comics to guide their thinking in the design process. The first comic depicted "the disappearance of major traditional characters of several current products" (p.30) while the other made fun of current designs for human-machine interaction. As indicated by these examples, industrial design involves the design of products for the consumer.

Instructional design.

Perez, Johnson, and Emery (1995) studied instructional designers who were given the task of designing instructional materials for a simulated diesel engine. Participants were given a 5-page summary of the material before they began designing, and they were allowed 2-1/2 hours to develop the instruction. Kirschner, Carr, Sloep, and van Merrienboer (2002) asked students from the Open University of the Netherlands and professional designers from Arthur Andersen to design preliminary outlines for an instructional unit on environmental consulting. Participants were given a list of design principles and asked to rate the top three principles that they would use when designing instruction. Then, they were asked to use those principles to create their outline of the instructional unit. Similarly, Rowland (1991) asked student and professional instructional designers to create an outline for physics instruction that would enable learners who completed the instruction to repair two different types of machines that repeatedly experienced mechanical failures. In each of these design challenges used with instructional designers, the ultimate goal was to produce instructional material relevant to the topic at hand.

School-aged designers.

McLaren and Stables (2008) studied students ages 10-13 as they designed new concepts for snack packaging that would accommodate active peoples' need to have a snack handy but also need to be able to carry it while still keeping their hands free. The design challenge included the constraint that the pack must be able to carry a high energy bar, a banana, a bottle of water, and a pack of nuts and raisins. This example represents a challenge related to industrial design; however, it is not meant to suggest that all school-aged design challenges are focused on industrial design. In fact, challenges for school-aged children can be developed to suit the subject matter under investigation. In this study, students' skills in design were fostered along with domain specific knowledge about marketing, ergonomics, prototyping (construction) methods and skills, and operating equipment.

All of the examples of design challenges explained in the previous sections are good examples of the ill-structured nature of design problems. A close investigation of any of these challenges will reveal that, for each of them, there exists no pre-determined right or wrong answer. Further, all of the information needed to design a solution to the problem is not available to the designer. These are typical characteristics of design problems, and educators interested in implementing design-based learning in their classroom should take heed to consider the format of their design challenges carefully. If the problem is specified in too much detail and the constraints are such that the solution is limited, then the problem space can become very structured and disallow the creative, divergent thinking that is inherent in authentic design challenges.

Fostering Design Thinking

Jonassen (2000) pointed out that design problems are arguably the most complex and ill-structured types of problems. They generally require integration of multiple domains of knowledge, which can be a difficult task for novices who are just beginning to master the knowledge of their primary domain. Furthermore, there is no single or “correct” solution to a design problem as there is in math or physics. Instead, solutions are rated using more abstract measures such as “creativity,” “inventiveness,” “originality,” or “innovation” (e.g., Christiaans & Dorst, 1992; Dorst & Cross, 2001; Hardre, Ge, & Thomas, 2006). The world is inundated with complex problems that require expert skill and knowledge from a broad range of disciplines. Studies of design behavior assert that expert designers are adept at solving such complex problems and aim to enhance our understanding of how such experts operate so that we can better prepare students to address such challenges in their futures. Researchers have suggested a variety of strategies for enhancing the development of design expertise. A summary of researchers’ suggestions is provided in Table 2, and each study is elaborated on below.

Author(s)	Strategy
Dixon (2010)	• encourage use of multiple types of mental representations (propositions, analogies, metaphors) • encourage use of between-domain analogies • teach design principles and heuristics explicitly
Atman, Cardella, Turns, and Adams (2005).	• gather ample information while working in the problem space • consider multiple potential solutions • transition between the problem space and solution space frequently • pay adequate attention to each phase of design
Casakin and Goldschmidt (1999)	• provide sources for visual analogy and explicitly encourage the use of visual analogy
Casakin (2011)	• encourage students to use metaphorical reasoning – particularly in the

	problem space
McDonnell, Lloyd, and Valkenburg (2004)	• use “digital storytelling” as a means for students to reflect on the design process and enhance transfer of design skills

Table 2: Summary of Instructional Strategies to Foster Design Thinking

Dixon (2010) conducted a verbal protocol analysis of six mechanical engineering students and four professional mechanical engineers to determine how their mental representations differed as they solved an engineering design problem. Participants were asked to think aloud and describe their process as they redesigned a motorcycle for rugged terrain. He concluded that experienced designers use a wider variety of mental representations such as propositions, analogies, and metaphors than student designers. Furthermore, experienced designers use more between-domain analogies than novices. Consequently, he recommended that students be encouraged to use not only relevant formulas and within-domain knowledge to explore the problem space but also other types of mental representations that encourage them to explore beyond the surface features of a design problem. Dixon also recommended that students be explicitly taught how to use design principles and heuristics to develop strategies and evaluate their design solutions. Such activities can help them build stronger cognitive structures and make their metacognitive processes more efficient and accurate.

Atman et al. (2005) also used verbal protocol analysis to compare the design behavior of freshman and senior engineering students. They discovered that the less experienced freshman designers did not spend ample time analyzing the problem and devising alternative solutions. In addition, all of these student designers – freshmen and seniors – seemed to spend insufficient time in the *project realization* phase early in the design process and the *evaluation* phase late in the design process. As a result, they suggest four elements of design that are crucial to developing a quality solution and should thus be incorporated into classrooms to foster greater design skills:

1. gathering enough information covering an adequate number of categories;
2. considering multiple alternatives during design development;
3. transitioning between design steps throughout the process; and
4. paying adequate attention to each step in the process (including setting up the problem and progressing through the final steps (p. 151)

Casakin and Goldschmidt (1999) compared the design behaviors of beginning design students, advanced design students, and professional designers to determine how each of the groups utilized visual analogies in the design process. Some participants were given tools for visual analogy and explicitly instructed to use those visual analogies, while others were given the same tools but not given explicit instruction to use the tools. The research findings confirmed that designers who effectively incorporate analogies into the design space produce more successful design solutions, and those who are explicitly instructed to do so are more successful than those who are not. They suggested that students of design benefit from instructional strategies that provide visual models and encourage students to incorporate the use of visual analogy in developing solutions to the design problem. Similarly, Casakin (2011) studied beginner and advanced architecture students' use of metaphors in design problem solving and suggested that metaphorical reasoning is a strategy that all design students should be encouraged to utilize during their work in the problem space; however, he also noted that novice designers do not benefit from the use of such reasoning when working in the solution space – perhaps because of their limited experience and resulting inability to make analogies. Educators who implement metaphorical reasoning strategies would be well advised to use caution when scaffolding students in their usage of these tools.

McDonnell, Lloyd, and Valkenburg (2004) suggested an interesting approach to enhancing the development of expertise that may be valuable across a wide range of design disciplines. They asked industrial design students to video record their entire group process as they solved a design problem. Once they had arrived at a solution to the design problem, the groups were asked to review their videos and then edit them to create a narrative video story of their design process. The researchers found that reviewing and editing video footage of themselves enabled students to critically reflect on their own behavior as well as their group's behavior. Furthermore, they found evidence that students were able to transfer some of their understandings of that specific design task to design in general.

Potential Benefits and Challenges of Design-Based Learning

Although design-based learning is a relatively new instructional strategy that educators are implementing in environments other than typical design fields such as industrial design, architecture, and engineering, many agree that design-based learning activities can provide students in all types of classrooms the opportunity to apply the skills and knowledge of multiple disciplines in relevant, meaningful ways (Blasetti, 2010; Fortus et al., 2005) while developing critical 21st century skills. While support for design-based learning has been steadily gaining momentum for the past fifty years, empirical research on such learning environments, particularly in K-12 education, is limited. The studies described thus far have investigated gains in students' critical and creative thinking skills, identified the cognitive behaviors of design thinking, and explored the differences between novice and expert designers; however, the majority of such studies have been conducted in environments other than K-12 classrooms. The following sections explore what the literature has to say about the potential benefits and challenges of design-based learning in K-12 classrooms.

Potential benefits.

The potential benefits of utilizing design in the K-12 classroom have been studied on a limited basis. Some of the literature reviewed reflects empirical research on the matter, while other resources aim to present a more opinion-based perspective about the benefits of design-based learning. Given the limited amount of available research, though, each piece of information investigated provides insight to drive future research.

Perhaps the most comprehensive summary available on research related to design-based learning in the K-12 classroom comes from Davis et al. (1997), whose book *Design as a Catalyst for Learning* summarized data from a variety of sources. The research team surveyed over 160 public school teachers about how they use design in the classroom; conducted direct observation in ten different schools; conducted qualitative face-to-face interviews with teachers, principals, school district administrators and coordinators, parents, and students in those ten schools; and, finally, they conducted interviews with education faculty members at colleges, state- and district-level curriculum specialists, and other educators with design-based learning experience. Their findings revealed that there is a wide range of potential benefits to utilizing design in the classroom. In general, the authors argue that design-based learning environments "reinvigorate learning and…model the integrated, dynamic processes we expect students to use as responsible, successful adults" (p. 19). Specifically, they reported that teachers support design as a part of their curriculum for the following reasons:

- enhancing flexible thinking skills
- promoting self-directed learning and assessment

- developing students' interpersonal and communication skills, and
- cultivating responsible citizens (p.19)

Teachers also reported design challenges allow "children with different skills and different 'ways of knowing' to contribute at different moments in the process and to present a variety of viewpoints throughout the process" (p.33). Certainly each of these qualities are critical components of the educational environments that foster the types of skills laid out herein as 21st century skills.

These researchers' findings, though, are not unique in the literature. Nicaise et al. (2000) investigated high school students' perceptions of an authentic learning environment largely similar to design-based learning and discovered that students "develop problem-solving skills and confidence in their own learning abilities" (p. 80). In addition, students acknowledged that they all practiced different skills and developed different kinds of knowledge, pursued their own unique interests and utilized different methods to achieve their goals, and took great pride in their work unlike the work they completed in other courses.

Doppelt et al.(2008) conducted a case study of design-based learning in an eighth grade science classroom and reported similar benefits from the learning environment. First, they suggested that the environment led students to feel more motivated because they applied their knowledge in a real-world situation. Second, the learning environment acknowledges and capitalizes on students' different learning styles and promotes active learning. Third, students developed communication, presentation, and problem solving skills because of the collaborative nature of the learning environment.

Carroll et al. (2010) also conducted a qualitative study of the implementation of a design curriculum in a middle school classroom. The authors presented their results according to three themes: *design as exploring*, *design as connecting*, and *design as intersecting*. With regard to *design as exploring*, the authors explained that students who participated in the study developed an understanding of their role as an active agent of change and began to develop the ability to empathize with others' needs – in other words, to explore the world around them more deliberately as a result of learning the design process. They suggested that the three most important aspects of the *design as connecting* theme were "risk-taking, expressing creative confidence in one's voice and collaboration among the students" (p. 48). In other words, students demonstrated a willingness to try new things, to express their ideas in group settings, and to work together to accomplish a common goal. Finally, with regard to *design as intersecting*, the authors discovered challenges or negative impacts of the learning environment. The author will explore this theme in the following section related to potential challenges of design-based learning.

Kolodner et al. (2003) also found potential benefits to design-based learning environments in K-12 classrooms. They asserted that learning environments that promote students as designers offer many affordances:

- Design challenges promote and focus learning, provide opportunities for application, and allow skill and concept learning.
- Students' construction failures are opportunities for testing and revising newly developing conceptions.
- Designing a working artifact naturally involves iterations in design; if done well, each can contribute to iterative refinement in understanding of concepts and gradual learning of skills and practices.
- Doing and reflection, aimed at helping students turn their experiences into accessible, reusable cases, can be easily interleaved with each other --

students' want to successfully achieve a design challenge provides a natural motivation for discussing the rationale behind their own design decisions, for wanting to hear about the designs and rationales of others, for identifying what else they need to learn, and for wanting to learn the science concepts that will allow them to come up with better solutions.

- Designing affords learning of communication, representation, decision making, and collaboration skills -- designers must show their design ideas to others and sell them. (pp. 504-505)

There are numerous other examples in the literature that report on the benefits of design-based learning environments. Rowland (1993), for example, suggested that design teaches participants how to manage “human factors such as communication, power, and anxiety as well as any conflicts of interest that arise” (p. 82). Lee and Breitenberg (2010) asserted that design-based learning environments foster important designerly skills such as “holistic thinking, empathy, imagination, creativity, visualizing problems and solutions” (p. 55) that are a top priority in today’s business environments. As pointed out by Naidu (2007), design tasks are “excellent vehicles for learning” (p. 252) and offer opportunities for critical thinking and collaboration.

Potential challenges.

While the potential benefits of utilizing design in the classroom are clear based on the authors above, the strategy is not without its limitations. Implementing a design-based learning environment is a challenging endeavor, and evidence to support this notion is also prominent in the literature. Doppelt et al. (2008) warned that although design-based learning can be highly motivating for students, its open-ended and ill-structured nature can also lead students to experience cognitive overload and thus cease learning altogether. “This is certainly the case when teachers attempt large design projects…. The task of navigating science content, the design process, and teamwork skills may be too much of a cognitive load….” they report (p. 24). Similarly, McDonnell (2012) noted that “even to be modestly successful at designing, a designer must be at ease with uncertainties, contradictions and with partial knowledge….to be at ease with working in a state of uncertainty, since it is such a state of partial knowledge that makes creation possible at all.” (p. 56). While tolerance for such ambiguity can be a challenge in design-based learning environments, it is also a worthwhile goal since it is a behavior demonstrative of critical thinking (Combs, Cennamo, & Newbill, 2009).

Carroll et al. (2010) explored *design as intersecting* as a theme that encompasses the connections between academic content learning and design thinking. While many researchers suggest that design-based learning can be an appropriate strategy for teaching content in subjects other than typical design fields (e.g., Davis et al., 1997), Carroll and colleagues revealed that their attempt to connect content in the learning environment was not as successful as they had anticipated. When students lack content knowledge as well as design knowledge at the onset of a project, then building content knowledge during the project is a difficult task. In order to mitigate this challenge, one must be clear about instructional goals first and use design thinking to support student learning. The authors suggested that instructional designers and educators who incorporate design into their curriculum should strive to create situations in which students are forced to consider possibilities by asking questions such as, “what if…” or “what might happen….”

Another potential challenge of design-based learning is collaboration. According to Snyder (2010), students who work in collaborative learning environments develop negative perceptions of the nature of the work involved. This is particularly true when they have to commit time outside of school to work with their group or even individually to accomplish their team goals. Snyder noted that some students complained that their group included members who did not contribute their equal share of the work. Carroll et al. (2010) also noted that students identified collaboration as a challenging aspect of the project. In their study, students reported problems such as little communication amongst the group members, team members not participating equally, and single team members trying to take over and do all of the work.

Finally, several researchers have emphasized that those who implement design-based learning must recognize time constraints as a real and significant challenge. Davis et al. (1997) explained that teachers already feel the constraints of time as they struggle to incorporate more and more content into their curriculum and sacrifice more and more days to standardized testing, thus it is imperative to clearly identify and adhere to a predetermined time frame so that teachers know what to expect with regard to how much time the implementation will require. Carroll et al. (2010) also found that both teachers and students acknowledged the time commitment involved when implementing a design-based learning curriculum. Students commented that, although the project was "cool" and "fun," it also "takes a lot of time" (p. 48), and they found the time commitment to be an undesirable feature of the process. The teachers who participated in the research also reported concerns about the time commitment involved in implementation.

In summary, there are a multitude of potential benefits to implementing a design-based learning environment in the classroom; however, there are also challenges that one must acknowledge before making the decision to utilize the strategy. Researchers have considered these potential benefits and challenges as they attempt to develop models of instruction for design-based learning in the classroom. The following sections describe the models that have recently been developed to help educators facilitate design thinking in the classroom.

Instructional Models of Design

Several models have been published to help educators facilitate design thinking. Some of the models are teacher-focused and use the design process to help educators build instructional plans. These include the Learning by Design model set forth by Kalantzis and Cope (Yelland, Cope, & Kalantzis, 2008) and the Understanding by Design model set forth by McTighe and Wiggins (2012). Since these models focus on designing instruction rather than using the design process in the classroom, the review below does not include these models. Other models, most notably the ones reviewed below, are student-focused models that aim to help educators incorporate design challenges and facilitate design thinking in the classroom.

Learning by design.

A group of researchers led by Janet Kolodner published a series of units they referred to as Learning by Design (LBD™) in the late 1990's and early 2000's (Kolodner, n.d.). This model of LBD™ was designed as a method to teach students science concepts while also teaching them scientific reasoning, project, communication, and collaboration skills. The Kolodner model of LBD™ is student-focused and students indeed do the work of designers when working through LBD™ units. According to Kolodner (n.d.):

> When we refer to designing, we refer to the full range of activities that a professional designer engages in to achieve a design challenge. A designer must understand the challenge and the environment in which its solution must function well. The designer must generate ideas, learn new concepts necessary for achieving the challenge (sometimes through systematic investigation), build models and test them,

analyze solutions, rethink and revise ideas, and iterate until a solution is found. Furthermore, designers communicate with clients and other stakeholders, collaborate, make informed decisions, manage complex sets of criteria and constraints, and need to adapt to changes as they arise over time. (p. 4)

Figure 4 shows a model of the LBD™ cycle devised by Kolodner. From the description above and the figure below, one can appreciate the iterative design cycle inherent in the LBD™ model.

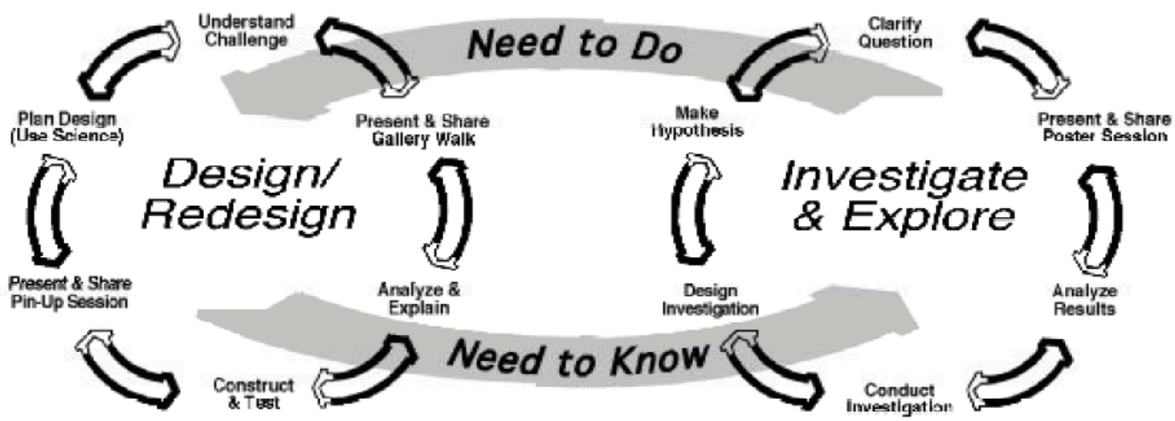

Figure 3: The Learning by Design™ Cycle
(Kolodner et al., 2003). Reprinted with permission.

LBD™ offers pre-designed instructional units for middle school aged children. The lessons walk students through the design process to learn age-appropriate science concepts.

Design-based science.

Design-based science (DBS) is "an inquiry-based science pedagogy in which new scientific knowledge and problem-solving skills are constructed in the context of designing artifacts" (Fortus, Krajcik, Dershimer, Marx, & Mamlok-Naaman, 2005). The pedagogy stemmed from the assertion that traditional science classrooms are not sufficiently preparing students with the ability to transfer their scientific knowledge to solve problems outside of the classroom setting. The DBS learning cycle begins as students identify and define the context of the challenge. Next they conduct background research relevant to the topic. Armed with additional information, students work individually and then in groups to build ideas about solutions. Teams progress next to build two- and three-dimensional prototypes, or artifacts, to represent the potential solutions. They gather feedback about those prototypes and utilize the feedback to inform the next phase of the design process. Figure 3 illustrates the DBS learning cycle.

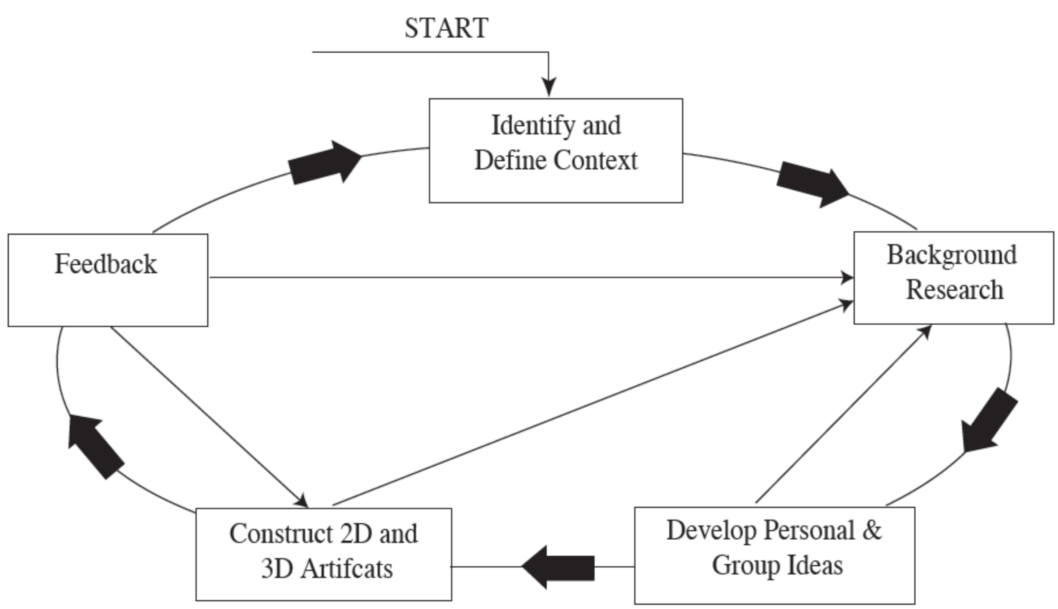

Figure 4: Design-Based Science Learning Cycle
(Fortus et al., 2005).

Fortus and his colleagues suggested that presenting students with real-world challenges and guiding them through the design process to build solutions to these challenges was appropriate and necessary practice to building real-world skills that they can transfer to other environments in the future. “All new scientific knowledge and problem-solving skills are constructed in the context of designing artifacts as particular instances of solving ill-defined, real-world problems," they explain (Fortus et al., 2005, p. 857).

These authors argued that the DBS methodology fosters students' ability to transfer their knowledge to new environments for several reasons. First, information is presented and investigated in multiple contexts and is therefore usable in a variety of new settings. DBS also fosters *learning for understanding* because it helps students develop an understanding of the "structural relations within a problem" (p. 860). This understanding leads students to the ability to make generalizations that can be utilized in other problem solving situations. Another reason DBS fosters transfer is that students learn information in context instead of as isolated facts. As a result, students develop *sagacity:* the ability to be discerning in their judgment of information. Finally, DBS emphasizes metacognitive practices through reflection activities that enhance students' ability to transfer.

PBS design squad model.

The PBS Design Squad Nation hosts a web site with resources for anyone interested in introducing young minds to the concepts of design and engineering. The educator's guide available on the site is a component of the Intel® Education Initiative and contains design activities for students ages 8-12 (WGBH Educational Foundation, 2012). Their model of the design process includes the following phases: *identify the problem, brainstorm, design, build, test, evaluate, redesign,* and *share*. Figure 4 illustrates this model.

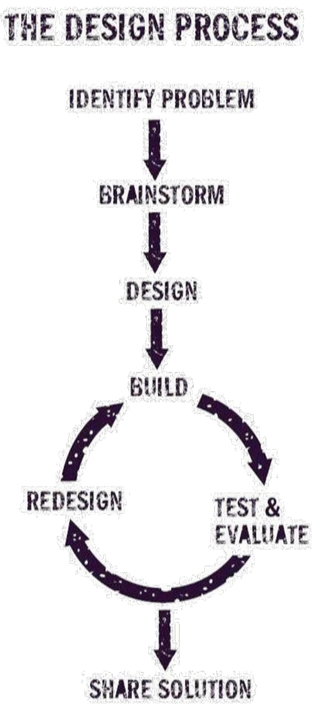

Figure 5: PBS Design Squad Model of the Design Process.
(WGBH Educational Foundation, 2012).
Reprinted with permission.

During the first phase of this design model, activity leaders help students *identify the problem* by explaining what the activity is about, asking students questions about who might benefit from the project, reviewing the rules, and then clarifying questions (WGBH Educational Foundation, 2012). Next, students *brainstorm*. Activity leaders encourage students to work in teams to write down as many ideas as possible – no matter how wild. Creativity and spontaneity are crucial behaviors at this juncture in the design process. During this phase, students might explore the materials available to them, sketch potential ideas, and refer to books, web sites, or other resources for inspiration. Next, during the *design* phase, students refine their ideas and select one or two to explore further. They think about how they will use the materials available and ensure that they have the resources they need, and they work to ensure that their idea is realistic and can actually be implemented. The next phases, *build, test, evaluate,* and *redesign*, constitute an iterative cycle in the design process. Students build a prototype of their design, test it and evaluate the results, and then redesign based on the feedback they gain during testing. Finally, the *share* phase is an opportunity for students to communicate their design solution and discuss how others will benefit from what they made.

IDEO design model.

IDEO is a global design consultancy with an entire department dedicated to design in education. Their model of design for K-12 learning environments includes five phases of design: *discovery, interpretation, ideation, experimentation,* and *evolution* (IDEO, 2012). Figure 6 illustrates this model.

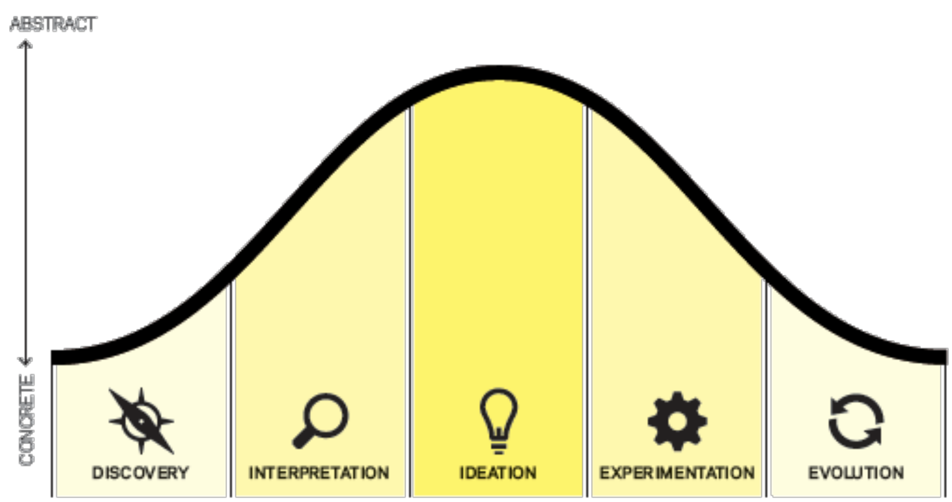

Figure 6: IDEO DesignModel
(IDEO, 2012). Image courtesy of IDEO.

During the *discovery* phase, designers work to understand the challenge, define the target audience, build a team, and share knowledge amongst team members. Next they prepare research by making a plan, identifying sources of inspiration, inviting participants, building questions, preparing for field work, and practicing research techniques. The final aspect of *discovery* is to gather inspiration by immersing oneself in the context to learn as much information as possible and seek inspiration. In phase two, *interpretation*, designers first tell stories to capture their learning from the *discovery* phase and share inspiration. They next search for meaning by defining themes to make sense of their findings and identifying insights. Finally, they frame the potential opportunities by creating visual reminders of the problem and generating action items from the insights they've gained. During phase three, *ideation*, designers generate and refine ideas. They prepare for and then facilitate brainstorming, narrow the results to promising ideas, evaluate the ideas for their realistic potential, and then build those ideas further. With a battery of ideas to work with, designers next make prototypes and get feedback during the *experimentation* phase, designers make prototypes of their design solutions and solicit feedback through planned questioning and conversations. Finally, during *evolution*, designers evaluate what they have learned by first integrating their feedback into the design and then defining a successful outcome for the challenge. Based on the parameters for success, designers ultimately build the experience they envision by identifying what's needed, pitching their concept, building partnerships, planning and documenting progress, and sharing their stories.

Stanford d.school model.

The Hasso Plattner Institute of Design (aka d.School) at Stanford University publishes a detailed model of the design process that they currently teach in their design school. Their model of design includes five phases: *empathize, define, ideate, prototype,* and *test* (Stanford University Institute of Design, 2013). Figure 7 illustrates this model of design.

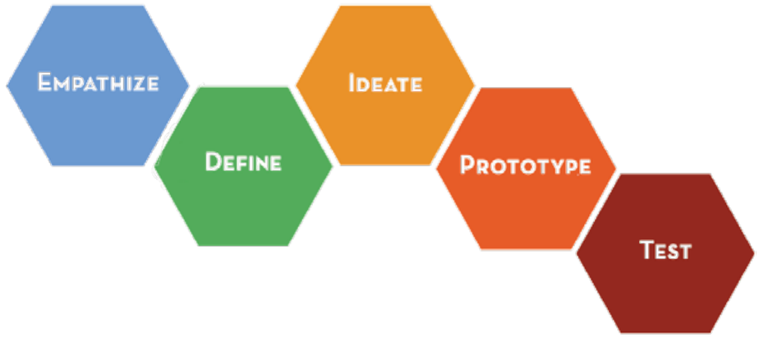

Figure 7: Stanford d.School Design Model
(Stanford University Institute of Design, 2013). Reprinted with permission.

The *empathize* phase involves interviewing members of the target audience for whom you are designing. The method encourages the designer to dig deep into the user's experience to find stories, understand feelings, and solicit emotion. Empathizing involves asking "Why?" often in order to find out what is important to the user. During the *design* phase, the goal is to capture the findings of the *empathize* phase. Activities in this phase encourage designers to define the user's needs and identify insights they gained that can be used as leverage for designing solutions. The result is a formalized point-of-view that states the problem to be solved within the constraints of the user's needs. Phase three, the *ideate* phase, is a time to generate as many potential solution ideas as possible. This brainstorming aspect of design should involve not only written ideas but also sketched ideas, which the designer shares with target users to obtain feedback. Based on that feedback, the designer works iteratively to develop new solution ideas that take into account the additional information. When this iterative ideation phase leads to what the designer believes to be a meaningful potential solution, the designer then moves to the *prototype* phase. This involves creating a physical model of the solution. The prototype is useful for allowing the target user to actually experience the potential solution in a low-fidelity form that the designer has invested minimal time and effort toward and can easily modify. During the *test* phase, the target user provides feedback to the designer. This feedback also initiates an iterative *prototype/test* cycle that continues until a satisfactory design is achieved. With each iteration of the *prototype* phase, the fidelity of the design increases and the model becomes more sophisticated.

Summary

The preceding literature review indicates that design is an iterative process used to solve ill-structured problems through solution-focused thinking that aims to generate something new and useful. The process of design is executed in two primary spaces called the problem space and the solution space (Neely, 2007). Design skills can indeed be learned, and students who possess skills in design are more adept at communication, collaboration, creativity, and critical thinking (Cross, 1982; Lewis & Bonollo, 2002). Multiple studies have revealed strategies that may foster design skills in students. Teachers can provide students with practice using analogical and metaphorical thinking (Casakin & Goldschmidt, 1999; Casakin, 2011; Dixon, 2010), teach design methodologies explicitly (Atman et al., 2005; Dixon, 2010), encourage students to reflect on their processes through strategies such as digital storytelling (McDonnell, Lloyd, & Valkenburg, 2004), and provide students the opportunity to use the design process to work with real-world clients to solve problems relevant to their personal world (Lewis & Bonollo, 2002). While these suggestions offer useful advice for educators to heed when implementing design-based learning, Nicaise et al. (2000) echoed the sentiments of many when they asserted that research with school-aged students is lacking. Furthermore, little research exists to help us understand the experience of a design-based learning environment from the perspective of the participants – i.e., students and teachers. We know little about what students and teachers perceive to be the benefits and challenges of design-based learning. Nicaise et al. noted that these perspectives are important to educators and instructional designers whose goal is to design optimal learning environments for a specific target audience. Doppelt and Schunn (2008) also urged that "further research needs to be undertaken to explore pupils' perceptions of their learning environment." (p. 208). The current research will contribute to that knowledge base for the benefit of instructional design practitioners, educational researchers, and classroom teachers.

The burgeoning interest in design-based learning is frequently tied to an interest in developing a requisite set of new skills in students. Indeed, the call for transformative practices in education has seemingly never been more urgent than the current call for a new set of skills for students of the 21st century. In 2009 President Obama announced the *Educate to Innovate* initiative, which he launched with the words, "I want us all to think about new and creative ways to engage young people in science and engineering, whether it's science festivals, robotics competitions, fairs that encourage young people to create and build and invent -- to be makers of things, not just consumers of things" (Kalil & Garg, 2012, para. 4). Design-based learning environments offer the potential to build these types of skills in students. As pointed out by Cross (2006), design encompasses the "collected body of experience, skill, and understanding embodied in the arts of planning, inventing, making and doing" (p.1). Custer (1999) emphasized that teaching problem solving to students is not enough. Instead, we must ensure that we are clear about the *types* of problems students will face in the future and make a point of giving them the skills they need to address these types of problems and practice doing so. By teaching students the skills of design, we prepare them for their future by helping them learn to envision things that do not yet exist and work through real-world problems similar to the types of problems that adults investigate in their own work. Design problems, as previously explained, are ill-structured problems that are parallel to the types of problems we face in our world today. These problems have no distinct, single solution. Instead, there is a plethora of potential solutions, and the challenge to the designer is to devise a creative, meaningful, and relevant solution based on knowledge from multiple perspectives and domains.

While research on design has gained significant momentum as evidenced by the literature reviewed for the current study, we still remain largely in a position set forth by French in 1979 when he asserted that there is not “enough understanding, enough scholarly work on design, enough material of a suitable nature to make such teaching possible” (as cited in Cross, 2006, p.13). Cross (2006) reasserted this notion and declared that “we need more research and enquiry; first into the designerly ways of knowing; second into the scope, limits and nature of innate cognitive abilities relevant to design; and third into the ways of enhancing and developing these abilities through education” (p. 13).

The current study is aimed at exploring the perceptions of students and teachers who participate in a design-based learning environment. The methods implemented in the classroom are an example of the utilization of design as Davis (2004) described: design as a pedagogical strategy. This research has value for several reasons. First, the research will add to the small but growing knowledge base about design-based learning in public education. Second, because the goal of the research is to better understand students’ and teachers’ perceptions of the benefits and challenges of implementing design-based learning in a classroom, the research will inform the instructional design community and the broader educational community in general about how to implement design-based learning more effectively. Finally, since design is a form of complex problem solving (Archer, 1979; Jonassen, 2000), learning more about students’ and teachers’ perceptions of the benefits and challenges of using the design process will help instructional designers develop a better understanding of how to foster complex problem solving skills through design-based pedagogy. These are the skills that are increasingly emphasized by educational policy makers and highly valued by employers, so understanding them and learning how to better foster them is an important goal. Through the methods laid out in the following section, the current study will investigate teachers' and students' perceptions of the benefits and challenges of design-based learning.

Chapter 3: Research Methodology

This chapter describes the methodology of the study. It explores the purpose statement and research question for the study in greater depth. It includes a formal description of the research design and methodology as well as the context in which the research was conducted. Finally, it provides a detailed description of the research participants, data collection sources, and methods for data analysis.

The goal of the current research is to understand how to better implement design-based learning in formal K-12 classrooms by investigating the perceived challenges and benefits of one implementation of design-based learning in a middle school classroom. Using a case study methodology, the researcher investigated what two teachers and fifty-one students who participated in an eighteen-week design-based learning unit perceived to be the benefits and challenges of such a learning environment. The research aims to answer the following question:

What are eighth grade students' and teachers' perceptions of the benefits and challenges of design-based learning as it was implemented in a middle school classroom?

The goal is to produce a description of teachers' and students' perceptions of the benefits and challenges of design-based learning as it was implemented in this instance. As Nicaise et al. (2000) emphasized, "without the student perspective, structuring alternative learning environments to meet the needs of students will undoubtedly fall short. Their perspectives could and should help to transform teaching." (p. 82). Similarly, investigating teachers' perspectives will help instructional designers build learning modules that meet teachers' needs as well. Building awareness of these perspectives, then, will help inform design decisions for future, similar learning environments and help designers build instruction that utilizes methods to mitigate the challenges and capitalize on the benefits identified.

Research Design

To answer the research question and meet the ultimate goal of the study, the research is grounded in a qualitative case study methodology. A crucial aspect of case studies is that they are situated within a bounded system (Yin, 1994). This case is bound as an investigation of the perceptions of teachers and students who participated in the implementation of a specific design-based learning unit over an 18-week period at a middle school in southwest Virginia.

There are several different types of case studies. Yin (1994) points out that *exploratory* case studies are sometimes used as a prelude to further, more in-depth research. Since the goal of this research is to inform future iterations of research on design-based learning in the classroom, this study can be described as an exploratory case study. Stake (1995) also differentiates between various types of case studies. He describes a collective case study as a methodology used when the interest is in studying and comparing multiple cases to illustrate an issue. The section below titled "case selection" will describe in further detail the three cases utilized in the current research, which can also be identified as a collective case study. Stake also notes that, in educational case study research, the cases are generally either people or programs. We study them

> for both their uniqueness and commonality. We would like to hear their stories. We may have reservations about some things the people tell us, just as they will question some of the things we will tell about them. But we enter the scene with a sincere interest in learning how they function in their ordinary pursuits and milieus and with a willingness to put aside many presumptions while we learn. (p. 1)

Yin (1994) describes several advantages of a using a case study methodology. First, case studies allow the researcher to utilize a "variety of evidence – documents, artifacts, interviews, and observations" (p.8). Yin also points out that case studies are advantageous when exploring real-life events to answer "how" and "why" questions. This research will ultimately address the question of how students and teachers perceive design-based learning. Furthermore, several types of evidence are utilized to answer the research question. See the section labeled "Data Collection" for a more detailed description of the types of evidence utilized.

Case selection.

The current research is part of a larger, ongoing initiative that investigates collaborative, transdisciplinary, and design-based learning environments in an effort to identify methods to develop critical and creative thinking skills in learners. This larger body of work was conducted by a *studio team* that consisted of three members: the researcher, who was a graduate student in the Instructional Design and Technology program at the university; the studio head, who holds a Ph.D. in Instructional Design and Technology; and a third research associate, who also holds a Ph.D. in Instructional Design and Technology. The researcher joined this collaborative team in the year 2009, and the overall initiative to investigate critical and creative thinking began approximately four years prior to that.

The teacher participants for the current study were initially recruited through a presentation delivered to all eighth grade teachers at the school where the project was implemented. The other two members of the studio team – the studio head and other research associate – delivered the presentation to the teachers. The middle school in which the research was implemented was selected because the principal supported the work and wanted to give teachers the opportunity to participate in professional development and design-based learning.

After the presentation, teachers were given information about whom to contact if they wanted to participate. Ultimately, two teachers consented to participate in the research. The first teacher, Meredith, is an English teacher who has been teaching for ten years. Her actual name is replaced by a pseudonym in this report to protect her anonymity. Prior to this collaboration, she had never utilized design-based learning as a methodology with students in her classroom, but she explained that she utilizes a variety of project-based learning techniques on a frequent basis. The second teacher, Sandra, is a civics teacher who has been teaching for ten years. Again, Sandra's actual name is replaced by a pseudonym in this report to protect her anonymity. Prior to this collaboration, she had never utilized design-based learning as a methodology with students in her classroom. She described her teaching style as authoritative and explained that students are trained about her expectations and classroom rules very early in the semester. The author was not involved at the outset of the current investigation as teachers were recruited but rather joined the project after teacher participants had already been established.

During the summer before implementation, the studio team worked with these two teachers for approximately six hours per day over the course of nine days to train them on design thinking and design-based learning methods and collaboratively plan the 18-week student curriculum. During this training, teachers explored their school year schedules and decided to implement the instruction with students in their first block (see more about block scheduling in the section labeled "Context of the Investigation"). Thus, students had no role in choosing to participate in the design-based curriculum.

It should be noted that the teachers who volunteered to collaborate in this research and allow their students to participate are likely unique from other teachers. While multiple teachers were recruited, only two volunteered to participate. These two teachers mentioned that they did so because they wanted to take a risk and they needed something fresh in their “bag of tricks” to keep them interested in their work. Not all teachers are looking for such opportunity or are willing to take such risks. In determining the boundaries of this case study, it was important to consider that each of the two teachers involved in the collaboration teaches a different subject and also works within different time constraints because of their block schedules. Consequently, their unique perceptions are each considered a separate case within the confines of the current study.

The students’ perceptions have been compiled and are also collectively considered a single case. The decision was made to define the students’ perceptions as a single case rather than unique individual cases since they all participated in the same learning environment and received the same instruction. Thus, this study consists of three cases: the perceptions of 1) an English teacher, 2) a civics teacher, and 3) fifty-one eighth grade students who all participated in a specific implementation of design-based learning over the course of eighteen weeks.

Context of the investigation.

The researcher and two eighth grade teachers (collectively, the *implementation team)* implemented a design-based learning environment with fifty-one eighth grade students once per week over an 18-week period at a public middle school in southwest Virginia. The school follows a block schedule, which provides larger blocks (90 minutes) of instructional time to promote more hands-on instructional time. The block schedule framework is organized with four blocks of instruction per day. Students receive 90 minutes of math and English instruction per day for the entire year. They receive 90 minutes of science instruction per day during one semester and 90 minutes of civics instruction per day during the other semester, so they are never studying both science and civics simultaneously. The fourth block each day is for elective courses. Students in each of the three blocks Meredith teaches are enrolled in her English class for an entire year. Students in each of Sandra's three blocks are enrolled in her civics class for one semester. During the other semester, they are enrolled in science class. Both teachers decided to execute the design-based learning environment with their first block students.

As the researcher, teachers, and two other studio associates (collectively, the *planning team*) planned the instruction over the summer prior to implementation, we considered how to engage students in civics and English topics to ensure that the learning environment covered required learning objectives from the teachers' state mandated Standards of Learning. The teachers ultimately decided to engage students in solving a problem related to civic responsibility. After much discussion and idea generation, they decided to utilize a *This I Believe* activity that they already planned to implement with the students at the beginning of the year as a launching pad for the design challenge. Students would read excerpts from the book titled *This I Believe: The Personal Philosophies of Remarkable Men and Women* (Allison et al., 2007) and then generate their own personal philosophy statement. This activity would serve as a starting point for students to start thinking about what issues in their world they would like to work toward solving. The original design challenge was thus very broad: *Identify a problem in your immediate world and design a realistic and meaningful solution to that problem*. Teachers planned to frame the challenge by posing the following theme to the students: "What is *your* better?"

While the teachers each recognized the importance of incorporating civics and English topics into the curriculum to meet their classroom learning objectives, they also discovered during their summer training that a design-based learning methodology lends itself well to utilizing knowledge from multiple subject areas. The teachers personally utilized knowledge from a variety of domains as they designed the curriculum during their summer training session. Since the planning team believed that students would also utilize knowledge from domains other than just civics and English, and since we wanted to give students an opportunity to publicly demonstrate their ultimate solutions, the planning team partnered with the local science museum to host a public Design Faire at which the students would exhibit their solutions. Students thus ultimately designed a solution to a problem in their world *and* built an interactive exhibit to demonstrate that solution to the public.

Design model.

The Stanford d.School model of design was utilized because of its simplicity, its available resources, and its grounding in research at the university level. At the time of this implementation, the model included five phases of the design process: empathize, define, ideate, prototype, and test. While the other models described herein follow very similar processes, the d.School model seemed to offer the appropriate amount of scaffolding for students at this level. This model was also a favorable model to adopt because the d.School web site offers resources that are free to download, and the publishers grant permission for anyone to modify the resources as they deem necessary. The ability to modify existing resources to meet the needs of unique learning environments made this design model a beneficial one. Finally, this model was the most attractive option for inclusion in the research because it was developed by professional designers through collaborative research in a reputable university environment. These five phases of design, listed and summarized in Table 3, provided the framework for all of the work conducted with the students over the course of the semester.

Design Phase	Description
Empathize	Observe/interview/interact with members of the target audience to gain a better understanding of how they are impacted by the problem at hand.

Define	Utilize the knowledge gained during the empathy phase to develop a point of view from which the problem is framed.
Ideate	Generate as many potential solution ideas as possible. Generate not only a large number of ideas but also a wide variety of ideas.
Prototype	Build low-fidelity physical representations of ideas to test their applicability and worth.
Test	Test prototypes with target users to help understand how to improve the solution. Helps to identify what aspects of the solution are inaccurate or incomplete.

Table 3: Summary of d.School Design Phases

With the project scope and the phases of design in mind, the planning team developed a general plan for the instructional sequence. The team acknowledged that the plan needed to remain broad and flexible due to the unpredictable nature of design environments but nonetheless laid out an initial framework for the instructional sequence. Table 4 shows this initial plan.

Week #	***Date***	***Planned Instruction***
0	8/21/2012-8/24/2012	*Meredith: Team Building/Community lessons during the week; Sandra: This I Believe, Citizens/Community Responsibility during the week*
1	8/30/2012	Introduction to the project; Mini design challenge (from d.School materials) *Meredith: This I Believe Essays, What is my better?; Sandra: Introduce project, What is my better?*
2	9/6/2012	Problem finding/empathy/define
3	9/13/2012	Field Trip to university
4	9/20/2012	Ideate/prototype activities
5	9/27/2012	Principles of design/Principles of community
6	10/4/2012	Review/summarize design phases
7	10/11/2012	Iterative work through empathy/define/ideate phases of students' specific problems
8	10/18/2012	
9	10/25/2012	
10	11/1/2012	Begin prototyping phase
11	11/8/2012	Iterative work through prototyping/testing and looping back through earlier phases, as needed
12	11/15/2012	
13	11/29/2012	
14	12/6/2012	
15	12/13/2012	
16	1/2/2013	

	1/3/2013 1/4/2013	
17	1/10/2013	
18	1/17/2013	
	2/9/2013	Science Museum Exhibit Day

Table 4: Pre-Implementation Plan

This general plan guided the implementation team's activities over the course of the semester; however, as expected, the students' progress dictated the actual course of events as the semester progressed. The specific actions and the sequence is described in the section labeled "Implementation" in Chapter 4.

Role of the Researcher

As a participant observer in the process as well as the researcher, I recognized that the students' and teachers' perceptions held much information that would offer valuable insight into how to mitigate the challenges of the environment and capitalize on the benefits. This realization led to the research question that became the focus of this study.

As a "primary instrument for data collection and analysis" (Merriam, 1998, p. 7) in this study, it is important to recognize how my background, values, and biases may shape interpretation of the data. During my time as a graduate student over the past several years, my work and research has been focused on critical and creative thinking, transdisciplinarity, and design-based learning environments. During the 2011-2012 school year, I co-taught a transdisciplinary course for graduate students who were challenged with the task of utilizing technology creatively to design an educational product that could be used to teach science. I have also collaborated with workplace peers to design and deliver workshops on critical and creative thinking, transdisciplinarity, and design thinking to public school teachers, and I have developed a firm perspective on the value of designerly thinking in educational environments. I believe that design-based learning environments hold potential to be a transformative force in the realm of education, thus I must acknowledge my support for this methodology in the context of this investigation and assert that I worked to remain objective in my data collection and subsequent analysis. The data collection and analysis sections below note the strategies used to mitigate bias in the research.

Data Collection Procedures

To establish students' and teachers' perceptions of the benefits and challenges of design-based learning, post-implementation data was collected from fifteen of the students and both of the teachers who participated in the design-based learning environment. Data was collected through post-implementation interviews with these participants as described below. While the students' and teachers' responses to the interview questions served as the primary data source to answer the research question, the researcher also utilized artifacts collected from all fifty students during implementation to confirm or refute the post-implementation interviewees' responses to the questions. Additional artifacts include:

- Students' responses to periodic reflection assignments in which they were asked to identify the challenging and beneficial aspects of the work.
- Researcher's field notes and reflections.
- Teachers' presentation to faculty colleagues during the week before school opening. This presentation was delivered voluntarily upon the principal's request and was intended to describe the teachers' training experience and their rationale for participating in the collaboration. The data included in this category include teachers' preparation and presentation notes as well the PowerPoint slides.
- Teachers' periodic written reflections during implementation.

Students.

The researcher randomly selected fifteen students to participate in post-implementation face-to-face interviews. Eight of the students were from the English teacher's class and seven of the students were from the civics teacher's class. A total of ten females and five males contributed to the student interview data. Each interview was audio recorded and conducted in a private room with only the researcher and the student. Each student was asked the following questions:

1. Describe the challenging parts of the process.
2. Why were they challenging?
3. Describe the parts of the process that were most beneficial.
4. Why were they beneficial?
5. Is there anything else you would like to say?

The researcher personally conducted each of the fifteen student interviews and transcribed the interviews upon completion.

Teachers.

A colleague who holds a Ph.D. in Instructional Design and Technology from the researcher's university conducted the interviews with teachers. This arrangement was agreed upon as a strategy for increasing the dependability of the results by increasing the likelihood that teachers would answer honestly and openly. The researcher met with the interviewer several days prior to the interview date. During this meeting, the researcher summarized her work with the teachers and students, provided an interview protocol form for each of the two interviews, and reviewed the interview questions to clarify any misunderstandings or questions. The researcher and interviewer also discussed the potential to ask probing questions to clarify and expand upon teachers' answers, and the researcher encouraged the interviewer to keep in mind the ultimate goal of the interviews – to identify teachers' perceptions of the benefits and challenges of design-based learning.

The interviewer audio recorded each interview and subsequently gave those recordings to the researcher to transcribe and code. The interviewer used the following script to guide her conversation with the teachers:

"Thank you for participating in this collaboration to implement design-based learning with your students. The researcher hopes to implement such a learning environment with other students in the future and would like your input. You responses will help determine how to better prepare future teachers in the most effective manner. Please know that the information you share will remain confidential and that your perceptions are valuable.

1. What do you perceive to be the benefits of design-based learning?
2. What do you perceive to be the challenges of design-based learning?
3. In what ways, if any, did your perceptions of the benefits and challenges of this learning environment change from before implementation to after implementation?
4. If your perceptions changed, why?
5. Is there anything else you would like to tell me?"

Data Analysis Procedures

Upon completion of the data collection, as the researcher I transcribed the audio-recorded teacher interviews conducted by my colleague and the audio-recorded student interviews I conducted personally. A detailed and procedural manner of data analysis ensued. I worked to move the data from a general to more specific nature through multiple iterations of coding the data. According to Creswell (2009), there are several steps involved in this process:

1. Organize and prepare the data for analysis.
2. Read through all the data to get a general sense of the information and reflect on its overall meaning.
3. Begin detailed analysis with a coding process.
4. Use the coding process to generate a description of the setting or people as well as categories or themes for analysis.
5. Advance how the description and themes will be represented in the qualitative narrative.
6. Make an interpretation or meaning of the data. Ask, "what were the lessons learned?"

Accordingly, once all interviews were transcribed, I began a methodical process to analyze each data set. I began with Meredith's interview, moved next to Sandra's interview, and finished my data analysis with the student interviews, which were combined into one large document and separated with a new page at each new interviewee. I utilized the process described next with each of the three transcriptions.

I first double-checked the transcription I was analyzing for accuracy. Before coding the data, I also read through the transcription multiple times to get an overall sense of the information therein and reflect on its meaning. During the first iteration of coding, I highlighted all key words and phrases that held potential significance. I used a green highlighter to mark potential benefits and a yellow highlighter to mark potential challenges. Next, I re-read the interview transcript. During this second iteration, I added comments in the margins to indicate potential themes, make note of potential secondary data to support or refute the text, and pose questions about the meaning. These comments also served as memos for the codes and helped to ensure consistent definition of the meanings derived during analysis.

As I read through the transcripts multiple times and highlighted significant text and added notes, I began to see the benefits and challenges more clearly. I thus compiled the perceived benefits and challenges into a list for each individual case. I next sorted the items on the list into potential categories. Initial categories for students included working together, time, real-life preparation, learning, narrowing the topic, and listening to others. Initial categories for teachers included benefits to teachers, benefits to students, assessment, knowledge/content benefits and challenges, and life skills/critical and creative thinking benefits and challenges. The lists, which summarized what had emerged as the meaningful information from each transcript, became a summary from which I continued my work to derive meaning in the data. Using all three lists together at this point, I began to see categories and created tallies of how many items on the lists fell within each category.

Next, I began sorting through the secondary data sources for evidence to support or refute the developing categories. I re-read my personal reflections that I recorded after each session, read the reflections that Meredith submitted throughout the semester, and read the students' reflections that they had submitted throughout the semester. Interestingly, this analysis of secondary data helped me to see that the categories I created often contained both benefits and challenges. As I looked for refuting data, I discovered that such data often supported some other data. For instance, I found data to support the notion that students did not like collaborating. This supporting data certainly refuted the evidence I had that showed students found the collaborative aspect to be a benefit; however, it supported the data that I had that showed students found the collaborative aspect to be challenging. As the dichotomy of the results became more clear, then, I brainstormed different ways to tell the story that developed during the coding.

It is important to not only use the data to describe the benefits and challenges of the environment as perceived by the students and teachers, but also to move beyond description and analyze it. The process of generating categories or themes from the coded data was an important step in generating such an analysis. As I reviewed the data collected and made notes about the pieces of information that seemed most significant, I constantly tried to remain objective in my assessment.

After the information was developed in the narrative format found herein, I shared it with each of the participating teachers to verify that they agree with the assertions made. Only one of the two teachers, Meredith, responded to my request for feedback. Her only comment was that her real name had been inadvertently used in the document twice. I corrected the oversight. Other than that, Meredith commented that the document was very interesting to read and that she did not disagree with any of the information contained in the results.

I also shared the results with the two studio associates who participated as part of the planning team before the implementation began. Their reviews helped reduce the chance of researcher bias in the data analysis and also helped me clarify any misunderstandings in the language before a final document was produced. Both of the studio associates responded to my request to review the document.

All who reviewed the results agreed that they accurately represented the events that transpired during implementation, but I did make changes to the format of the data presented to clarify some misconceptions pointed out by the reviewers. First, they were confused about the population of students to which the results referred at different sections in the document. Sometimes, the data reflected student interviewees only; other times, it reflected all fifty students who participated in the research. I accordingly edited the results to clarify any misconceptions in that regard. Also, the readers did not feel that there was enough demographic information about the students who participated in the research, so I added additional details about the students involved in the study and the school system in which the school is located. A third concern related to the themes that arose. One reviewer commented, “Was there any point at which any one of [the] perceived benefits were also a challenge (or vice versa...and the same with the students)?” Since the answer to this question was yes, I modified the format of the results chapter. Instead of organizing the results according to the benefits and challenges, I decided instead to present the results according to the themes that developed during the analysis. Themes that contained both benefits and challenges were more clear using this organization scheme.

Strategies for Validity and Dependability

Validity, according to Creswell (2009), is one of the strengths of qualitative research. Creswell also explains that qualitative validity “means that the researcher checks for the accuracy of the findings by employing certain procedures” (p. 190). As the researcher, I employed several procedures to ensure the accuracy of the data:

1. Triangulation: As described above, data was gathered from multiple sources including:
    - Interviews with randomly selected students from each of the teacher’s classes
    - Students’ responses to periodic reflection assignments
    - Teacher interviews
    - Teachers’ reflections during implementation
    - Researcher reflections, field notes, and notes from weekly teacher/researcher meetings

2. Member checking: As the researcher, I transcribed, coded, and analyzed each teacher's interview and corresponding supporting data separately. I then shared that analysis with the participating teachers to ensure that they agreed with the meanings derived. Furthermore, I shared the analysis of the students' compiled data with both of the teachers to seek their consensus on the assertions made. These methods were employed to help reduce the potential for researcher bias in the data analysis. I sent both participating teachers a copy of the results once the data was analyzed.
3. Extended interaction with research participants: Since the researcher was directly involved in the implementation of the design-based learning environment over the course of an entire semester, the field notes collected reflect the perspective gained through interaction with all of the participants.
4. Peer review: As the researcher, I shared the analyzed data with the two studio associates who helped plan the implementation during the summer prior. Their review also helped reduce the chance of researcher bias in the data analysis and helped to clarify any misunderstandings in the language before a final document was produced.
5. Clarification of researcher bias: I have described herein the factors impacting researcher bias and the measures taken to overcome them.

I also followed the recommendations of Gibbs (2007) and double-checked all data for transcribing errors, used constant comparison analysis to avoid drifting meaning of codes, and wrote memos about each code to ensure their consistent definition.

Reliability in the traditional sense of replicability is more difficult to ensure in qualitative research. Instead, the researcher aims for dependability of results. Dependability refers to the idea that readers of the research will agree that the conclusions made are reasonable given the data collected (Merriam, 1998). To help to establish dependability of any assertions and conclusions made in the research, I utilized direct quotations from the students and teachers, when applicable. Furthermore, the strategies utilized to minimize researcher bias and described herein also help to establish the dependability of the report.

Chapter 4: Results

The results of this study are based on interview data gathered from each of the two participating teachers and fifteen of the student participants. The interviews were conducted after the implementation was complete. The goal of this chapter is to generate a description of teachers' and students' perceptions of the *benefits* and *challenges* of the design-based learning environment implemented in this specific setting. This information will help instructional designers and classroom teachers capitalize on the benefits and mitigate the challenges as they design for such learning environments in the future.

As previously indicated, this research is a multiple case study. The teacher's perceptions are presented individually as two unique cases, and the students' perceptions are combined and presented as a third case. The results are presented in this chapter first by individual case. Next, a cross-case comparison is made to investigate the similarities and differences across cases. Before investigating the results of the data analysis, it is important that the reader have a clearer understanding of the implementation itself. The following sections describe the major events that transpired.

Implementation

As the researcher, I met with the teachers and students one day per week for 90 minutes. Since neither of the teachers' classrooms was large enough to accommodate all 50 students, we held our weekly meetings in the school's auditorium. Students moved from their homeroom to the auditorium directly after morning announcements and usually arrived approximately 15 minutes into the 90-minute class period. The auditorium space is generally used for school performances and has rising rows of free standing chairs and a stage at the front. Since students needed space to work in their groups and since the chairs, although movable, were not easily relocated, teams often stationed themselves on the stage and in the open areas on the floor directly in front of the stage and at the rear of the auditorium. On days when it was clear that teams would need tables on which to work, I unpacked tables from the storage closet and placed them in the open spaces around the room. Since the space contained no place where students could store their work from week to week, students transported their work materials from the classroom to the auditorium for each meeting. To ensure that students had access to necessary information, I also checked out a cart of laptop computers from the library and transported them to the auditorium. Per library rules, students had to sign their name to a chart to indicate which computer they used that day. This workspace was not an ideal one for the project, but it was the only one available so we worked within our constraints. Due to these constraints, our actual weekly work time was significantly less than the original planned 90 minutes and generally lasted approximately 70 minutes. The following sections provide a detailed description of the implementation following the d.School framework.

Introduction/background knowledge.

Before giving the students formal instruction in design thinking, the implementation team immersed them in an initial mini design challenge during our first group session. Student teams were given uncooked spaghetti noodles, string, tape, and a marshmallow and asked to build the tallest free-standing structure possible that would support the weight of the entire marshmallow with no help (Wujec, 2010). They were given 17 minutes to complete the task. At the close of the activity, we led a group session to talk about how team members approached the challenge and identify the salient features of design behavior that students utilized.

After the introductory marshmallow challenge session, the implementation team utilized several sessions to help students continue to study the skills involved in designing. First, we took them on a field trip to the researcher's university to participate in workshops on (1) the importance of multiple perspectives and individual talents, (2) the factors that influence design decisions, and (3) another design challenge. Back at the school the following week, we immersed students in yet another mini design challenge based on the d.School gift giving experience (Stanford University Institute of Design, 2013). This time, we modified those materials and asked students to redesign the morning commute for their partner. Once again, at the end of the activity, we talked about the importance of others' perspectives, but this time we pointed the instruction toward the importance of understanding the perspective of the people for whom you design solutions rather than the people with whom you design solutions. We also utilized one session to help students build community, trust and respect among their team members. Following these activities, we began working more diligently to help students identify problems in their world for which they wanted to design a solution and learn how to empathize with the people who are impacted by those problems.

As previously mentioned, students began the year with a *This I Believe* activity which led them to identify problems in their world on which they wanted to focus. Next, the teachers compiled a master list of these problems and students each ranked their top three interests from the list of problems. Teachers placed students into teams of four or five students based on these rankings, and each student got their first or second choice of topics. We thus formed a total of twelve different groups, each of which worked on solving a unique problem in their community. Once these groups were formed and students had been given sufficient opportunity to explore the design process through mini design challenges, we began more formal progression through the phases of design as student teams worked to develop solutions to the problems they had identified.

Empathize.

In order to help students understand how to empathize, I led a discussion on perspectives and used examples of different perspectives on a clean bedroom. Students next began to think about the problems they had identified and that their team would try to solve. They identified the people who were impacted by this problem and listed what they thought were the important considerations with regard to that population's perspective. Finally, they developed a list of questions that would help them understand the problem more clearly from their perspective.

Empathy work was a difficult phase for the students. Middle school students are only beginning to develop the cognitive ability to see things from a non-egocentric perspective, and abstract relationships are beginning to form in their minds (Manning, 1995). It was quickly evident that they lacked some of the requisite skills needed to build empathy, so the efforts of the implementation team turned toward helping them learn to identify their target audience more definitively and formulate questions that might help them understand the problem from the perspective of their target audience. We placed students in groups with their team members and conducted a brainstorming session with them to help them build ideas about the information that they wanted/needed to know.

In the days following this empathy activity, I reviewed and commented on each brainstorm board to each of the twelve teams. Teams were asked to consider the comments and return the following week prepared to discuss the feedback as a group and prepare questions to ask members of the target audience. This was their second attempt at preparing questions for audience members. Students still had difficulty, so the implementation team spent another session helping students formulate those questions more concretely. Once students' questions were more clear, we sent them to interview members of their target audience so that they might identify their problem more clearly.

Define.

Based on the information students gained during their interviews with target audience members, the implementation team next turned to helping them redefine the problem from the perspective of those people. Students were asked to rewrite the problem statement in the form of a "How might we…" question and clearly describe a typical member of the audience impacted by the problem they are solving. Finally, students were asked to identify three constraints that would impact the decisions they make about how to solve the problem.

Once each group had completed this information, the teachers and I implemented the first public critique session. We divided the groups into three different classrooms and asked each group to share the following information with the other teams in the room:

- Clearly state your problem in a "How might we…" format.
- Identify three constraints that will impact the decisions you make about the solution to your problem.
- Identify any ideas you have, at this point, about your solution.
- Identify what resources you may need as you continue to work on your project.

While teams shared this information, each student observing the presentations used a form to provide feedback for the group. All teams were asked to review the feedback and identify how and why they would or would not utilize the feedback. This was the first situation where students experienced a form of public critique of their ideas and it gave them the opportunity to think critically about their plan and utilize feedback to improve it.

Ideate.

The implementation team next asked students to begin developing storyboards of their solution ideas. We conducted a mini-lesson on storyboarding to help students build an understanding of what such a storyboard might look like, and we shared samples with the group. Once students had built a solid storyboard based on the feedback they had received, they prepared for another public presentation of their progress. This time, they presented their ideas not only to their classmates but also to external reviewers including the principal, the assistant principal, the instructional coach, and the other two members of the planning team from the summer. Each reviewer filled out a feedback form while the teams gave their presentations and, following the presentations, each reviewer met with the teams to give them oral feedback and clarify the information they put in the feedback form. Based on this feedback, teams were asked to identify how they might modify their work to clarify any questions or misconceptions identified during the critique session.

Prototype.

During the next phase of the process, student teams began building models of their solution ideas. While their storyboards certainly represented an initial model, they were tasked in this phase with utilizing all of the knowledge they had gained thus far to build a more comprehensive physical prototype of what their solution would be. The prototyping phase gave students the opportunity to naturally and formatively critique other teams' ideas. Students visited other teams' work areas as they were building/designing prototypes and naturally asked questions and provided feedback. This informal evaluation environment motivated the teams to incorporate the feedback from their peers into their projects, but they also got the opportunity to share their work in a final public critique once their work was in a final state.

Test.

The implementation team invited external reviewers to participate in a final critique of student work in a session during which each team set up a formal display of their work as it would be displayed at the science museum in the upcoming weeks. Teams gained feedback about the fine details of their presentation that needed to be polished before their public presentation of their final work. In the session following this public critique and before the public exhibit, the teams modified their presentations to incorporate the feedback they received. Finally, as a culmination of the project and a means of formally testing the products, students displayed their products and shared their presentations with the public during an all-day open house at the local science museum in February of 2013.

Teachers' Perceptions

The teachers' perceptions of the benefits and challenges of the learning environment are each presented as a unique case below. Both of the teachers' names have been changed in this report to protect their anonymity. Their perceptions are unique and presented as separate cases not only because they are unique individuals with perspectives that are shaped by their experience and epistemology, but also because their courses are structured entirely differently within the block schedule that the school follows. Meredith, an English teacher, works with her students for the entire year. Sandra, on the other hand, is a civics teacher who only works with her students for one semester. These differences place unique types of pressure on the teachers to cover their required curricula within their given time frames, so their perceptions of the benefits and challenges of this learning environment may indeed differ. Despite these differences, the interview data revealed that the teachers had very similar perceptions of the benefits and challenges of the learning environment. Figure 8 summarizes the teachers' perceptions of the benefits and challenges. Because there are both benefits *and* challenges to some of the aspects that the teachers discussed, the sections below present the findings according to the themes that arose during data analysis.

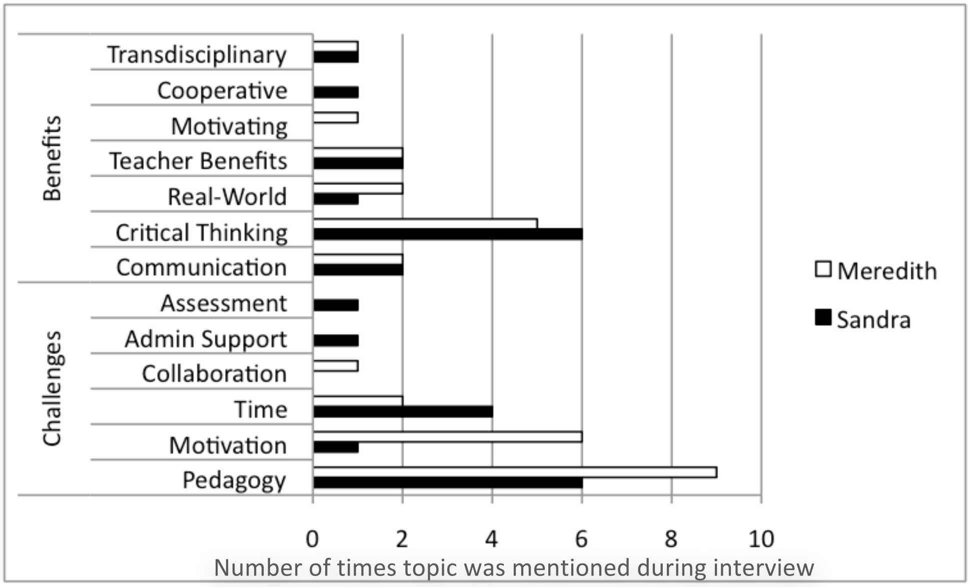

Figure 8: Summary of teachers' perceptions of benefits and challenges

Meredith.

Meredith's classroom is arranged with student desks in groups of four around the room, and a quick glance at the room's perimeter shows evidence of students' group projects, different types of art supplies, and an overall structure that lends itself to collaboration. According to Meredith, the students in her first block who participated in the collaboration are average to below average in their ability level. They are students who do not take advanced courses and require more support than students in her other classes. She described these students, in general, as non-college-bound.

As Meredith discussed what she perceived to be the benefits and challenges of design-based learning, she described aspects that impacted not only her students but also herself. With regard to her students, Meredith discussed critical thinking, real-world experience, communication, transdisciplinarity, time, ambiguity, and motivation. Personally, she discussed how her own pedagogy was impacted by the environment. Each of these themes is explored in more detail below.

Critical Thinking.

Meredith explained that she found one of the greatest benefits of the learning environment to be the way it challenged her students to think in new ways. While she, like other teachers, is constantly trying to stretch her students intellectually, she perceived that the design curriculum enabled her to do so much more naturally. She explained that the open-ended nature of the design challenge, and the fact that no single right answer existed to the challenges that the students faced, made this intellectual stimulation an inherent part of the process:

> I think it stretches them rather than the paper/pencil, the "explain in an essay" [method]. It makes them think more outside the box…it asks them to challenge themselves in a way that most students today don't. They want to get the right answer right away, and this forces them to think and rethink and reconsider and push themselves in different directions.

Meredith mentioned that students do not normally have the opportunity to do the types of activities that they did during this project in school unless they participate in a program for gifted students – which her first block students do not. She felt that giving students the opportunity to think in this way helped prepare them for the type of work they will do in their lives after they complete their education.

Data extracted from the reflections that Meredith completed during implementation support this post-implementation assertion about the critical thinking benefits of the learning environment. In one of the reflections she completed during implementation, she mentioned the knowledge she personally gained as she participated in the training sessions over the summer.

She noted that she was prepared to help her students learn to think in a different way because she had learned to think in a different way as she learned about design:

> I think that I already knew that they have to care about what they're doing in order for it to really foster critical and creative thinking, but it is more cemented in my brain as to why I give them choice in their projects… They've been trained in quite a different way, and we're having to take them backwards – back to how we learn before we ever start school… through experience, trial and error.

Meredith also acknowledged in her weekly reflections that the empathy work students were required to conduct was beneficial to their thinking process. "The benefit is in the development and analysis of the initial questions as well as in the reflection at the end. They have to evaluate their work along the way."

Real world experience.

Meredith also identified the authentic, real-world experience that design-based learning provided for her students as a beneficial aspect of this project. First, the curriculum afforded students the opportunity to learn in the classroom the same way they learn outside of the classroom. She perceived that students were learning in a much more authentic manner, by "playing and experimenting and trying and pushing the boundaries. That's how we learn what rules are. That's how we learn language, that's how we learn what our bodies can do, that's how we learn everything." Further, Meredith asserted this real-world learning environment was valuable because it gave students the opportunity to see that teachers are not the only source of knowledge in a classroom. Instead, students discovered that they are in control of their own knowledge gains and will be more capable of problem solving on their own in the future. She suggested that the environment helped transform her students from "kids that view knowledge as a funnel that someone pours into their head and then they pour out on a piece of paper," into students who are "able to apply problem-solving to every aspect of their life."

Meredith also noted that the kind of works students did during this project gave them real-world experience doing the kind of work they will be asked to do once they obtain jobs after school. She discussed the model of work that Google uses as an example: "The dream jobs that the kids want, like they want to go work at Google. Well, Google doesn't work independently by yourself. They have an office that has no walls, no barriers, and you're constantly working with other people. And we're like, 'okay, schools should be more like that.'"

Communication.

Another beneficial aspect of the project, according to Meredith, was the range of communication skills that students practiced throughout the project. First, she found benefit in the fact that students got the opportunity to share their ideas with public audiences and get feedback to improve their project. Meredith described how the first public critiques helped the students move their projects along. During this critique, students listened to presentations from other teams and provided feedback about what they perceived to be the confusing aspects of the information they presented and the strengths and weaknesses of the team's project thus far. Meredith explained that as students critiqued other groups' projects and gave them feedback they learned a lot about their own processes. She noted that when students began "presenting and getting feedback from someone other than their group and someone other than us [the teachers], … the kids kind of saw, ooh that group's really got it going on and we don't! And what did they do differently?" The ability to listen to others is certainly a crucial aspect of good communication, and Meredith's comments indicate that she noticed her students learning this aspect of communication through public critiques.

Meredith also described how the students' skills progressed in terms of giving valuable feedback. As they participated in public critiques as well as frequent informal critiques with the teachers or peers in their class, she noticed that students got better at modeling their ideas and sharing information about their own process. In other words, their ability to provide meaningful feedback improved as the semester progressed.

Transdisciplinary.

Meredith emphasized the breadth of topics that you can cover when utilizing a design-based methodology as a benefit. As she described the planning phase of the project during her interview, she acknowledged that she and Sandra both recognized how many skills they could cover with this project:

> When we created this project we didn't really look too much at our SOLs. We realized this covers so much of the basics that we want, the foundations. And so we realized, it's going to cover them…. But when we had to put it into a formula for one of our in-services…we thought, wow! It fits this, it fits this, it fits this, it fits that…when we actually looked at it we thought, wow! It meets so much…but it also meets so much more. It meets more of the things that we want to make sure students have that they can take with them to any class, not just ours.

Indeed, the data from the presentation that Meredith and Sandra presented to their faculty colleagues during the week before school opened supports the idea that the teachers perceived the process to be beneficial in terms of the broad range of skills and topics that can be covered. That presentation included a slide with the following presenter notes to go along with it: "Don't be afraid…don't be an old dog…[design is] transdisciplinary – no future job is based on one discipline."

Pedagogy.

Not only did Meredith identify beneficial aspects to design-based learning from the perspective of benefits to students, but she also discovered that implementing a design-based learning environment afforded her several personal benefits. First, she found value in the process because, as she was working to help her students learn about design thinking, she was practicing it herself. She explained that this metacognitive practice helped strengthen her own design skills. For example, when the students "stalled" during the empathy stage, Meredith described the problem as a design challenge itself. "We were problem-solving our own design challenge, thinking, 'How do we change this? How do we do this better?' Because what we planned didn't work." She noted later in the interview that "the stuff that we want our kids to do with changing their ideas and what they think is going to work, we were having to do that constantly." Meredith acknowledged that she was learning to incorporate design thinking into her own practices as she implemented a design-based learning environment with her students. Further, this realization that the process she was teaching her students was also the process that she was utilizing herself helped her believe even more strongly that she was indeed teaching her students valuable real-world skills.

Another personal benefit that Meredith recognized was the opportunity that this project afforded her in terms of evaluating her own pedagogical decisions and challenging herself with a new methodology. Her discussion on this topic was passionate:

> I worry when teachers aren't challenging themselves to really look at the learner and what they're actually gaining versus what they can spit out and regurgitate. Because a lot of times we think they're getting this and they're NOT. So in order to find out how effective we are we really have to be willing to see the things

> about ourselves that we don't want to see and the things about our great lesson that weren't so great. So I think that challenging ourselves is huge. I still 110% believe that there's not a teacher in this building that can't benefit from doing this.

Meredith explained that developing a design thinking mindset herself through this process helped her feel more comfortable with recognizing her own shortcomings in the classroom. If a team that she was working with did not wholly understand the concept she was trying to help them develop, she had to strategize alternative ways to help them internalize the information they needed to use. She did not see these shortcomings as failures, though, but as opportunities to improve – evidence itself of a design thinking mindset.

Time.

The most significant challenge that Meredith identified was time. First, she asserted that the time span of the implementation was far too expanded. "I think the time span really smacked us hard with not doing it in a concise time frame and making it so sporadic and spread out over the course of time," she explained. She suggested that instead of spreading the project out over eighteen weeks it would have been more effective if we had met more frequently over a shorter time frame. If we had met daily for a month, for example, we would not have had to use time to "rebuild momentum each week." Furthermore, because we did have to spend time rebuilding momentum each week, there was not enough daily time at each session to accomplish all that we wanted to accomplish with students.

Time was also a challenging aspect of the environment from Meredith's perspective because of the extra time that was required for planning instruction and finding appropriate scaffolding for students. We had twelve unique groups all working on different problems. "We wanted it to be more authentic and more real and for them to care about it," Meredith explained, "but it made it harder for us to help them gather resources. So we weren't able to scaffold them in that." Meredith learned that her time would have been much easier to manage if she had not made the scope of the project so large but instead asked each group to focus on the same problem.

Ambiguity.

Another challenging aspect of the implementation, for Meredith, was overcoming the ambiguity of the learning environment. She reported that she had difficulty determining how to scaffold students who wanted to quit when they faced this ambiguity. Students found it difficult to tolerate the uncertainty that they faced, she explained, because

> they're so used to a cookie cutter system in school. So they want to have the right answer, they want to get the A, they want it to be easy and to be a 'right there' answer and there just isn't. Sometimes we don't even have the answer…we have to go and research it with them, and they're just flabbergasted by that sometimes. Just the open-endedness of it sometimes is a struggle.

Students did not have the benefit of a single, correct solution that they were working to find. Instead, they struggled with how and where to find relevant and reliable information that would help them devise a meaningful and innovative solution, and they often "stalled," in Meredith's words, because they were overwhelmed and did not want to risk failure. In her reflection after week 5, Meredith noted:

> They want to know if they're doing it "right" and are scared of failure. They want to know what we want from them and want to give the minimum for the maximum output. Very few kids (in either class) realize that what you put into

> things is in direct proportion to what you want to get out of them. Many of them have a hard time following directions and asking questions to clarify. They just assume they know what they're doing and go. How can we bridge the gap? I'm not sure. I try to have more open ended time in my classroom to help get them thinking differently and evaluating their work themselves, but it's a struggle.

Motivation.

Meredith also perceived student motivation as a challenge in nearly all phases of the design process. Early in the project, as students were learning to empathize with their target audience, Meredith noted that many students shut down because they did not know how to do the work. She concluded that this motivational deficit occurred because students did not feel empowered to accomplish their goals, and it was challenging to keep them motivated when there were so many different groups to scaffold. For example, the students who worked on the problem of war veterans feeling under-respected and under-appreciated for their service had a difficult time connecting with veterans to conduct empathy work. As a result, they simply did not do the work the first time it was assigned. "I guess to empower them we should have said, 'okay, I will meet you after school. WE will go there,' instead of 'you will go there.' Or bring someone from the veteran's hospital here. So to help them with the empathy stage."

Another aspect of motivation that Meredith discussed relates to students' lack of motivation to modify their ideas. Many students were married to their own ideas and were unmotivated to listen to any of their team members' suggestions. Further, once teams completed the initial prototype of their design solution, they were highly unmotivated to modify that product to make improvements. Iteration, in other words, was not something students were motivated toward:

> We saw them get beyond excited about the prototype that they had actually created. And we saw the buy-in there, and the problem after that was the whole test and build. They didn't want to. They didn't want to change it at all. They were like, 'What? We did this great thing! We're so proud of ourselves! It's done.'

Collaboration.

A final challenge that Meredith noted about the learning environment was the difficulty some students faced in working collaboratively with others. She described how some students became "married to their idea" and did not want to listen to the voices of others in their group. When students were unwilling to change, she said, it became very difficult for others in the group to work with them. Those students whose ideas were not heard became less motivated to contribute to the project and did not want to help develop an idea to which they did not contribute. Helping some students learn the skills of effective collaboration – i.e., acknowledging the ideas of all members of the group – was a challenging part of the project for Meredith.

In summary, Meredith perceived that the learning environment offered both benefits and challenges not only to her students but also to her personally. She asserted that the environment was beneficial to students because they learned critical thinking skills, gained real-world experience, practiced effective communication and collaboration skills, and utilized transdisciplinary knowledge and skills. Despite the beneficial aspects of the environment, there were also notable challenges. Meredith emphasized that the methodology was challenging because of a variety of issues related to time, and she also noted that she perceived student motivation as something difficult to maintain throughout the process. Many of the assertions that Meredith made were echoed in the themes that arose through data analysis of the post-implementation interview with her colleague Sandra. Those results are presented in the following section.

Sandra.

Sandra's classroom is configured with rows of desks in a straight line, and students are expected to follow a specific protocol when in her classroom. Sandra is very affectionate and animated with her students, and it is clear that she is heavily invested in their success in her class. According to Sandra, the students in her first block who participated in the collaboration are above average in their ability level. They are students who take advanced courses and do not require as much support as the majority of students.

Sandra found a wide variety of beneficial aspects to the design-based learning environment and, like Meredith, she found benefits to both her students and herself. She also acknowledge several challenging aspects of the implementation. Among the themes that Sandra identified as impactful for her students were critical thinking, real-world experience, communication, collaboration, transdisciplinarity, time, and motivation. Like Meredith, Sandra also perceived the environment to have an impact on her personal pedagogy. Each of these themes is discussed in the following sections.

Critical Thinking.

During her post-implementation interview, Sandra frequently described the learning environment as beneficial because it was "student-centered" and fostered "self-discovery." Students had control over their own learning, she explained. They identified their own problems to solve, devised their own solutions to those problems, analyzed information to determine what to utilize and what to disregard, determined which solutions they wanted to explore further, and set their own personal and team goals. "They're behind the wheel in terms of what direction they go in, and, in a lot of aspects, what pace," she explained, "and that's most important in today, with the age of SOLs and the rigor of memorization." Sandra perceived this independence that her students experienced as a benefit to the learning environment because it forced them to think for themselves, to make decisions about their own learning, and therefore helped prepare them for their futures in ways that more traditional learning environments did not. She stated:

> It was really cool to watch these kids get excited about what they were learning. And I saw a lot of that. And that's what I loved most about this, is the self-discovery and the student-centered push. And they don't get enough of that. In public school, they don't get enough of that… So I think, for a lot of these kids, it was fun for them to be in the driver's seat of what they were learning.

Real world experience.

Sandra mentioned the authenticity of the learning environment as a benefit multiple times and emphasized its value: "First and foremost I love the concept of design learning. I think it's awesome, and I think if you can hammer out the challenges, which I think is possible, the end result is authentic learning which will last forever." She also perceived that design-based learning is beneficial because it prepares students for the next level of education and offers them opportunity to practice 21st century skills. "It was good for them," she explained, "because [it's like] life. So it made it… I think it was a great way to prepare them for the next level of education."

Communication.

Sandra also perceived benefit in the experience students gained doing self-evaluations and evaluating others. Like Meredith, she perceived that students learned significant communication skills as they prepared themselves to present information to others and as they evaluated information that other teams presented to them. She explained, “when they present, there’s an amount of pride that goes with that, and they really have to know what they’re doing.” Presenting to a public audience, she argued, forces them to master the material so that they can communicate it effectively. Furthermore, she asserted that they gained valuable experience communicating their knowledge to diverse audiences rather than just peers or teachers inside the school walls. “They had to communicate to each other, to outside people through their interviews, through their presentations, and then at the Saturday science fair they had to talk to the public. That’s what I loved most about that day is listening to the kids talk to adults about what they did.” Indeed, as the students talked to members of the public about what they did, Sandra explained that she discovered how very much the students had learned – not only in terms of content knowledge about their particular topic, but also in terms of skills such as communication that they utilized throughout the semester.

Transdisciplinary.

Another beneficial aspect of the learning environment, according to Sandra, was that students were learning more than just one subject. She explained that “whenever you can incorporate all of your contents into one assignment…I think, is a major plus.” Like Meredith, Sandra entered this implementation with the position that design-based learning environments offer teachers the flexibility to cover multiple subjects at once. The presentation that she and Meredith prepared for their faculty indicated their perspective in this regard, as discussed in the section above on Meredith’s perceived benefits. In her post-implementation interview, Sandra referred to this as the “cross-curricular” aspect of the learning environment

Collaboration.

A final benefit that Sandra identified was the cooperative and social nature of the learning environment. She explained that she felt students truly valued the opportunity to work with their peers. While she acknowledged that cooperative learning does happen in other settings at school, she explained that this situation was different because students were working together for the duration of the semester – “more than just every now and then” like in other classes. She described the process as “social. Very social…” and perceived this to be a good thing for students this age, given their very social nature in general.

Time.

Time was a significant challenge according to Sandra. She, like Meredith, felt that there was too much time in between each session. “I think that probably was the biggest challenge that I could take,” she explained, “Because we only met once a week, and sometimes we had to skip a week, so the continuity of the process was tough. And the length, I think, that we incorporated it probably was tough.” Furthermore, the amount of time that she, as a teacher, had to commit to the process was a challenge. She acknowledged that this method required much more planning and preparation than other teaching methodologies she has used. She, Meredith, and I met once per week to plan, and she stated, “It probably, you know, in reality it probably needs to be done more. That’s a big challenge, I think, to educators…how much time outside of…okay, you’ve got your regular lesson planning, and then you’re going to have this, and so the time factor probably would be a big challenge.”

Motivation.

Sandra agreed with Meredith’s sentiments that maintaining student motivation was a challenging aspect of the project. She felt that it was very difficult to maintain students’ “focus and energy and intensity toward the assignment." Specifically, she acknowledged that students started the project with a high level of curiosity and excitement, particularly after they developed a firm idea about what they were actually going to be doing. As the semester progressed, though, Sandra explained, there was a "lull" and she found it very difficult "just being able to sustain their attention and excitement to the project." In Sandra's opinion, the students' inability to maintain focus may have been a factor of their maturity level or age. She suggested that perhaps it would be less difficult to maintain high school students' motivation but that it was too much for 13 and 14 year olds.

Pedagogy.

One of the more significant benefits that Sandra reported was that her perspective on her students' abilities changed significantly as a result of working through this process with them. Initially, it was very difficult for her to relinquish control of the learning environment to her students. "I had to relinquish control and it was good for me," she explained. As she did so and watched her students take charge of their own learning, she discovered that they stepped up to the challenge surprisingly well. While the process took time and Sandra did not fully recognize the benefit until the students presented their work at the final Design Faire, she ultimately acknowledge that she gained a greater respect for her students' abilities through this process. "It made me think differently," she said, "It just made me think differently about how kids think and what they're capable of."

The loss of control that Sandra experienced during this project created a lot of discomfort for her, and she noted that it was a challenge to let the students take ownership of their projects and still maintain order within the chaos of the environment. "This was extremely challenging for me, because I'm a control freak. And with this age group, it was a big deal for me because I don't always trust that they'll do their best," she explained. To mitigate this challenge, Sandra acknowledged that she felt the need to create structure within the chaos; however, it was a challenge to incorporate that structure without stifling the students.

Another pedagogically challenging aspect of the environment was incorporating subject-specific standards of learning. "The challenge for science and civics and, to some extent probably math, the challenge for those curriculums or content teachers is going to be connecting it to specific SOLs. So I think that's probably the biggest academic challenge." She explained that this challenge might not be so predominant for English teachers or teachers whose courses are not evaluated at end-of-course standardized tests, and she also acknowledged that such incorporation might become easier when working with a larger transdisciplinary team. "We only had English and social studies. Had we had math and science involved, it might have been easier because we could have all been sharing and brainstorming on how to connect it. But then that would have required more time."

Assessment.

Throughout the implementation, Sandra maintained a consistent focus on the lack of assessment that existed in the project. She also emphasized assessment as a challenging aspect of the environment during her interview. While I emphasized that providing students with oral and written feedback on their project was a valuable form of assessment, she insisted that students needed grades in order to analyze their progress and understand whether they were performing adequately or not. "In reality, these kids are like Pavlov's dog. They're used to having some type of assessment to check for their understanding and to check at least their work ethic and their attention to the task," she explained, and reiterated the importance of figuring out how to incorporate formal assessment without taking away from the authenticity that design-based learning environments offer.

Support.

A final challenge that Sandra discussed during her post-implementation interview was the notion of administrative and pedagogical support. She asserted that finding the necessary support to prepare teachers to implement this environment in the future would be a challenge. She urged that teachers would need time outside of the school year to learn and plan in a stress-free environment, and that teachers should be compensated for their time to do so. "To encourage the concept of design learning," she explained, "I think it would be cool if you could do a summer institute and taught teachers how to do it but then give them the opportunity to start planning out the logistics and just having some quality, non-stress time to map it out." Such opportunity, according to Sandra, is altogether unlikely, though, and an issue that would certainly need to be addressed in order to ultimately realize a goal of large-scale implementation of design-based learning.

The results from the teacher interviews reveal that they agreed upon many of the aspects of the learning environment that were beneficial and challenging. In particular, the teachers agreed that the environment was beneficial in terms of critical thinking, real world experience, communication, pedagogy, and transdisciplinarity. They agreed that the challenges of the environment were time and motivation. Meredith perceived the ambiguity and the collaborative aspect of the environment to be challenges. Sandra, on the other hand, perceived the collaborative nature to be beneficial. She also noted that challenges of design-based learning include pedagogy, assessment, and support. Chapter five explores these similarities and differences in detail. Interestingly, many of these themes that arose during the teacher interviews also arose during the student interviews. The results of the analysis of student data are presented in the following sections.

Students' Perceptions

The following sections describe the students' perceptions of the benefits and challenges of the learning environment. The findings are based on interview data gathered from fifteen of the fifty students who participated in the learning environment. Each of the student interviewees were randomly selected, and a total of ten girls and five boys participated. While there were a total of four minority students in the group of fifty who participated in the study, all of the students who participated in post-implementation interviews were Caucasian. Eight of them were students from Meredith's first block course, and seven of them were from Sandra's first block course. As previously mentioned, Meredith's students are, in general, non-college bound students and require more scaffolding. Sandra's students, on the other hand, are advanced students who require less scaffolding. Pseudonyms are used in place of students' real names to protect their identities.

In addition to data collected from interviews, this section contains supplementary data that is used to support the findings. This supplementary data was collected during implementation and includes responses and artifacts gathered from all fifty participating students. The reader should take note that the text contains special notation of any data that includes information from all students who participated in the study; otherwise, the data reported was derived from student interviews.

The themes that arose from analysis of student interviews share much in common with those that the teachers discussed. Those themes are: critical thinking, real world experience, communication, collaboration, multiple perspectives, time, learning, and motivation. Each of these themes is explored in depth in the following sections. See Table 5 for a summary of the data.

	BENEFITS						CHALLENGES					
Student Name	Collaboration	Communication	Multiple Perspectives	Real World Experience	Learning	Motivation	Collaboration	Communication	Multiple Perspectives	Real World Experience	Critical Thinking	Time
Amanda				•			•				•	
Jared	•				•						•	
Shannon	•	•	•	•	•		•	•	•		•	
Drew	•		•	•			•	•		•	•	•
Jasmine	•	•	•		•	•					•	•
Steve	•	•	•		•		•		•		•	
Caley	•			•			•		•	•	•	•
Brittany	•		•		•	•	•	•	•		•	•
Rachel	•		•	•			•		•	•	•	
Connor	•	•	•	•			•		•		•	•
Aimee	•	•	•	•		•		•		•		•
Erica	•	•	•	•	•		•	•	•		•	
Alicia	•	•	•	•	•	•	•			•	•	•
Chrissy	•		•		•	•	•					•
Julian	•	•	•	•	•		•		•		•	•
Total number of students (out of 15) who discussed the theme:	**14**	**8**	**12**	**10**	**9**	**5**	**12**	**5**	**8**	**5**	**13**	**9**

Table 5: Summary of Interviewees' Perceptions of the Benefits and Challenges

Critical thinking.

Thirteen of the fifteen students who participated in post-implementation interviews identified the thinking processes they utilized as a challenge. First, students found it challenging to narrow the focus of the problem that they initially identified so that it was directly related to their immediate world. This was a highly agreed upon challenge, with nine of the fifteen students discussing some aspect of narrowing the focus as a challenge. Students felt a level of discomfort as they worked to determine how the initial problems they identified (e.g., hunger, drug abuse, suicide, bullying, discrimination) manifested in their immediate world. They were required to solve a problem that they could clearly identify in their personal lives. Moving from broad topics to more specific and personally relevant issues was difficult. Alicia, whose team was working on the broad topic of animal abuse, explained the trouble her group had trying to identify a smaller, more meaningful problem that they could verify was existent in the community. “When we were picking our topic,” she explained, “really what kind of animal abuse we wanted to focus on. And then once we picked neglect, do we look at people not meaning to neglect their animals or people who do mean to? So kind of narrowing our topic down was a lot of [the challenge].”

Furthermore, the students struggled with coming up with a meaningful and feasible solution. As they delved deeper into their topics they became more invested in the problem. One of Drew’s comments illustrates the deeply invested mindset that several students developed during the process: “I don’t know, I guess we were just not used to doing that stuff. We’re still young minds, we wouldn’t think about how we could change the world, so just finally doing it…” The teams wanted to develop a product that would truly help address the problems they identified, and determining the best potential solution was a difficult process. That difficult decision was compounded by the constraints of the project in terms of time and resources, and many groups stalled at this phase of the project because they did not want to commit to a solution they were not sure would be meaningful. Alicia, for example, described the difficulty of working within constraints to identify a realistic solution: “it could be a crazy idea, but all the same it had to be in the realm of reality and it had to have some type of technology that can already do it a little bit, you know? So some things had to be already created and stuff.”

Students also noted that it was challenging to filter the relevant information as they conducted research. Their initial research about the problems they identified revealed large amounts of information that they had to sort through. Armed with new knowledge about the topic, students struggled with deciding which information was reliable and, of the reliable information, which information was relevant. As Jared and his team began to conduct research on suicide, for example, they discovered that there were a lot of factors to consider. They ultimately narrowed their focus to teen suicide, but still discovered that they needed to make some decisions about what aspect of the topic to focus on. Should they reach out to teens themselves, or should they focus on adults who interact with teens? He explained to me that he struggled with determining "if we were going to go to kids and give them information or adults. And we went with adults, since they don't know much about suicide (some of them)." Shannon explained that a challenging aspect for her was just finding the right information:

> "finding the information that we didn't know about it…and trying to all find the right information for it, I guess. It was…I don't know…researching it was kind of hard. It was hard to find the right information…Different web sites, if they say different things or whatever, trying to figure out which one is right, to help us move forward and find what's…more information on it that we didn't already know."

As students worked through the design process, then, they discovered that narrowing the focus of the problem based on empathy work with the target audience was difficult. As they gathered more and more information, they began to discover that not all of it was relevant to the specific problem they decided to solve, and filtering through the information to determine what was relevant was a challenge.

Real-world experience.

The students also acknowledged that the project was beneficial to them because the felt the work they were doing was truly important. Ten of the fifteen students interviewed identified this as a benefit of the project. As they explored the perspectives of others, the students reported that they began to internalize how people whose lives were different from their own were impacted by the problems they were working to solve. As a result, they took pride in the fact that they had the opportunity to make a real difference and help others with issues that they may never have even come to acknowledge had they not participated in this learning environment. Students explained that they felt like they had been given the opportunity to do something that not many other school-age children had experienced – that they were doing "grown-up" work. Aimee, whose team investigated the problem of bullying, echoed the sentiments of many students who participated in face-to-face interviews:

"A lot of people don't get the opportunity to actually do that, and so when you have just an idea in general that you're like, 'Okay, this is cool. We get to help bullying.' And then you're like, 'Well you get to go to a science museum at a mall and tell people about what you've been doing and stuff.' Its…I think it's really good, because you feel like you're actually doing something good, and that's like the best feeling ever."

Students also explained that the work they did helped them to realize how problems in the real world get solved. They acknowledged that even a small contribution such as their own towards a meaningful problem could have a significant impact that, ultimately, intensifies. While they sometimes perceived their contribution to the problems that they identified as small, they also acknowledged that the perspective they gained through the process helped them realize that a single person can instigate change that has a growing and lasting impact. Shannon's sentiments embody much of the meaning behind these lessons that students learned and reported in their interviews. She stated, "I just thought it was really cool to work with other people and see different ideas and how young kids can make such big things and can make things that can actually become real." Similarly, Amanda explained that she learned how "little things can help out. Just starting little to make it bigger."

The sheer excitement that students felt from being told that they were important enough to contribute to the solution of a real-world problem was a benefit in and of itself. Many students described their pleasure with doing work that is usually left to adults or college-aged students. Drew explained his excitement that he and his team mates had changed the world: "We're still young minds, we wouldn't think about how we could change the world, so just finally doing it…." Caley also commented that the program was beneficial because "we are at such a young age and we got to make a real solution to a big problem, and I just thought that was pretty cool." Steve confessed that "it was really cool to work with other people and see different ideas and how young kids can make such big things and can make things that can actually become real."

Students also reported that the real-world nature of the projects they worked on was helping to prepare them for their future. Since the problems they were solving were ill-structured and difficult to solve, they acknowledged that they were doing a type of thinking that they don't normally do in school. Steve noted:

> I feel like it kind of got me ready to go to high school and do more work… because we had to do a lot of work and actually use our brains. We didn't just have the answers right there in front of us. We actually had to think of stuff and really think and research to find stuff out.

Connor's comments also supported this notion:

> It was challenging, but I found it to be really fun. Like a good experience. Because it's a real world thing. It's something you would do at a college, do

> studies like that… you kind of felt like a grown up doing it, or a college student, because you got to go out and observe real world stuff and you got to have real people come in and look and your projects.

The students clearly appreciated the opportunity to work on a project that had an impact in their immediate community, and they perceived the work they were doing to be beneficial not only for that reason but also because it helped prepare them for the kind of work they will do in the future.

While the opportunity to participate in a project that had a real impact on real-life issues was certainly an aspect of the learning environment that students identified as a benefit, five of the students also recognized that the benefit did not come without its challenges. For one thing, it was a challenge because the solution had to be a realistic product that could be developed. Rachel struggled with this aspect of it as she and her team worked to solve a problem in the bigger general category of war. They originally brainstormed ideas about how to make soldiers' armor more reliable, but Rachel described the frustration she encountered as her team members pitched their ideas. Many of those ideas, she explained, came from fictional video games that her teammates played during their free time outside of school. She struggled to keep them grounded in the real world:

> [They] wanted to go off in the Black Ops and Call of Duty world, and that's where a lot of their ideas came from. And so it was really hard to kind of bring them back to reality and pretty much say building this kind of machine isn't going to happen in the real world… I don't think 14-year-olds can build that.

Aimee faced similar struggles as she and her teammates decided that they were going to design a robot that could detect bullying in the school hallways. "You had kind of set in stone something that you didn't actually think you could actually do. So you think you're going to let everyone down and just be like, 'Nope. We're not actually building a robot.'" The real-world constraints that the teams encountered, then, made the authentic nature of the project a challenge at times.

Communication.

Of the students who participated in post-implementation interviews, eight reported that one of the more significant benefits of the project was that they gained communication skills through the process. Not only did they acknowledge that they learned to speak more effectively to communicate their ideas to a group, but they also pointed out that they learned the importance of listening, an undoubtedly important aspect of effective communication. Shannon noted a benefit in learning to "communicate…with the other people in my group," and Connor explained that he learned "you definitely have to start…listening to people. You can't always be the person that wants to talk." Furthermore, the nature of the project forced students to practice their communication skills with a variety of audiences. When students presented their initial solution ideas to other teams in their class and solicited feedback, they gained experience presenting to their peers. When they presented their ideas at a public critique in front of school administrators and scholars from my university, students gained experience communicating their ideas to a more formal audience. Finally, as they shared their final products to members of the community at the Design Faire, students learned how to prepare a presentation that described their entire learning process. Aimee noted that she found it beneficial to be a member of a team as well as a larger cohort who were all presenting at the Design Faire. She said "the whole public speaking thing" was beneficial, and "it helped to be in the environment with all of the other people that we knew, from our grade, that were all around us and talking. It made it a lot easier than if we were the only people there talking to everyone.” They also gained experience vocalizing their processes and rationalizing their decisions as visitors to the Design Faire asked them questions about what they had done. Erica noted that “we didn’t really in our group we didn’t talk as much about our project. And then as people came up and they were asking us questions we were like, ‘Oh, we didn’t really think of this that much.’ So we kind of had to come together and think of responses, and it helped us with our project in a way.”

While students acknowledged that honing their communication skills was a beneficial outcome of the project, they also recognized that developing those skills was challenging. One-third of the students interviewed perceived communication to be one of the challenging aspects of the project. Students indicated that they found it challenging to communicate with members of their target audience, particularly if the topic about which they were speaking was a delicate one. Drew, for example, noted that he had a difficult time framing his questions so as not to offend the person he was speaking to: “One thing that was hard was, especially with obese people, you had to interview them. And we thought it would be kind of hard, because you don’t want to offend them.”

Students also admitted that communicating with members of their group that they did not know prior to the onset of the project was difficult. Shannon, for example, shared that she found it hard to “get used to talking to people I don’t know and actually getting along with them and stuff.” Her sentiments echo that of several of the students who participated in interviews. Finally, students noted that the different types of communication that they practiced made them feel challenged. Not only did they communicate informally to their teammates and more formally during interviews with members of their target audience, but they also had to practice effective communication through presentations that they delivered for the purpose of critique. Students noted that it was challenging to prepare information that was appropriate for the different types of audiences to whom they presented their information.

Collaboration.

Fourteen of the fifteen students who participated in the interviews identified some aspect of collaboration as a benefit of the environment. First, many perceived the collaborative aspect to be beneficial because it gave them the opportunity to build relationships with people whom they may not have otherwise ever befriended. Students were placed into groups with students from their own class as well as from the other class, so they had to work with students they did not know prior to this experience. Students explained that, even though being placed in groups with people they did not know bothered them initially, they ultimately appreciated the opportunity to meet and form relationships with new people. Some students also appreciated that they got to work with friends from another class that they normally did not get to interact with during instructional time. This friendship aspect of the collaboration was a frequent theme during student interviews.

Students also reported that the collaborative nature of the project taught them to work effectively in a team of people with diverse ideas and opinions. Twelve of the fifteen students who participated in interviews agreed that the collaboration was beneficial. They learned to work with and get along with others that they did not usually interact with, and they perceived this to be a skill that will benefit them in the future. Similarly, as students worked with diverse team members, they learned that their personal approach to problem solving may differ from someone else's approach and that there was something to be gained from understanding and incorporating others' approaches into their own. They discovered that others' work habits had value that they could incorporate into their own work habits, and they discovered that the diverse range of skills that others brought to the group was beneficial as they worked to accomplish a shared goal. Aimee noted that she benefitted from a modified perception of her teammates as a result of the process:

> The teamwork part of it was really good. When I first was like, ‘Oh. I’m working with Julian. And Chloe. And Matthew.’ But then I’m just like, “Okay, well they might actually be able to do this.’ And so we were doing it. We had some challenges of course, but then I found out that he was actually a better worker than I thought. So that was good.

Another interesting finding about the beneficial aspects of the collaboration is that students became closer as a cohort altogether. They began to feel part of a significant force that was working to do good in the community, and they took pride in being a member of that group. Erica summarized this notion well: “We learned, I think, not just in our group but with the other groups with us, we all kind of became closer as eighth graders. Everyone just became better friends. And we really started caring more about our society and the issues that are happening.”

While students discovered many benefits to the collaborative nature of the learning environment, many also acknowledged that collaboration was quite a challenge. Twelve of the fifteen interviewees reported challenges related to the collaboration involved in the project. First, they asserted that it was difficult to ensure that everyone in the group did their fair share of the work – particularly the work that had to be conducted outside of the classroom. Brittany noted, “I think getting all of the people in our group to do something while we were out of school was kind of hard, because a lot of them didn’t really want to participate when they’re doing other things.” On the other hand, some students noted that particular team members wanted to take over and do everything while other students tended to shirk their responsibilities and contribute a less significant portion of work than their teammates. It was difficult for some teams to find a balance and make sure that everyone contributed equally to the final product. Erica described the challenges her group faced in this regard: “A couple of people in our group didn’t care as much as other people did. So they kind of figured that we would just do everything while they would just sit down and kind of put in their input once in a while. And they didn’t do their homework, and they didn’t really pitch in as much effort as they should have….”

Students also explained that they had a hard time trying to incorporate everyone’s ideas into the project. Sometimes, each team member held strongly to their potential solution idea(s) and the teams had difficulty coming to a consensus. Shannon described this conundrum well:

> [The biggest challenge was] probably working together with everybody and having to put everyone’s ideas together and make one big idea. I think that was really hard, because some people didn’t want to do what other people wanted to do. So then we had to put it together into one big thing that we all agreed on. So I thought it was hard agreeing and trying to get everyone in the group to agree with everything.

Finally, collaboration was particularly difficult for the students at the onset of the project because they did not understand the work habits and perspectives of group members they did not know. Students found it challenging to make progress toward identifying their goal and determining who would be responsible for what because they had not yet learned enough about the strengths and weaknesses of their teammates.

Interestingly, students recognized the significance of collaborating even at the onset of the project. After the first meeting with students, during which they participated in a mini design challenge to build a marshmallow tower out of spaghetti noodles, tape, and string (Wujec, 2010), students were asked to reflect on the most challenging aspect of the day, the most beneficial aspect of the day, and what they learned from the day. The responses of all fifty participating students, summarized in Table 5, indicate that they recognized collaboration as a significant factor that is both challenging and beneficial.

Most Beneficial	**Learned**	**Most challenging**
• Building • *Talking to team mates* • *Seeing others' designs* • Talking about strategy at the end • Hands-on activity • *Working with different people* • Getting up, moving around • *Team work* • Brain gym • Adrenaline	• *Listen to each others' ideas* • *Teammates strengths, weaknesses* • *Teamwork is important* • Failure is OK • Harder than it looks • *Everyone's input counts* • *Working with people is better than working alone* • Plan first! • *Teamwork leads to success* • *Project needs expertise from multiple areas, therefore teams are good* • *Compromise*	• *Collaborating* • *Learning each other's work ethics* • Getting it to stand up • Supporting the marshmallow • *Sharing ideas with the team* • Not enough spaghetti • Working without a plan • *Too many ideas* • What shape/type of structure to build • *Putting all ideas together* • Keeping the tower from leaning • Breaking spaghetti • *Compromising*

Table 6: Students' Reflections After Mini-Design Challenge
(italicized items relate to collaboration; summary of all fifty students' responses)

Multiple perspectives.

Another common theme in the student interview data was that students found significant benefit from exposure to the perspectives of others. Twelve of the fifteen students interviewed identified this aspect of the environment as a beneficial one. First, they explained that the empathy work they conducted as they interviewed members of the target audience for whom they were designing was rewarding. It helped them understand what people who are different from them go through and thus made them begin to care more about problems in the world that did not necessarily affect them directly. One student, Connor, whose team explored the issue of obesity, noted, "I didn't really have an idea of what obesity was like because I'm not really big like that. But it kind of helped me understand what those people go through, and not what it feels like but kind of understand how they look at the world and look and themselves. And how they view themselves." His explanation exemplifies the sentiment of many students: through the work that they did to empathize with their target audience, they developed a perspective that they would not have otherwise explored.

Not only did students benefit from exploring the perspective of their target audience, but they also reported that exposure to their team members' differing perspectives was beneficial. Students learned how team members' different ideas could interact to create a stronger solution. They sometimes discovered, as they learned to listen to others, that their teammates had unexpectedly good ideas that they themselves would never have thought of. Connor explained that "taking into consideration what [other people] say" is really important, and that "sometimes you have to sit back and listen and take their ideas in and stuff like that." Students clearly realized through this process that everyone thinks differently and, by exploring others' ideas, even recognized that their own thought processes could be improved by incorporating those of their team members. Steve, a student who actually described the need to incorporate and acknowledge others' perspectives as a challenge, also noted that such challenge resulted in meaningful benefit. He stated that the challenge "helped me really think about things and grew my mind bigger than it actually was. I think outside the box, and stuff like that." Similarly, Shannon stated, "I think that it's good to get other people's ideas on things and not just your own, so then you can have a better idea and use everybody's opinions on things. Because it can help sometimes."

Rachel found a broader angle to the benefit of others' ideas. She pointed out that it was beneficial to get to see the perspectives of more than one teacher as well as other students, and she appreciated the feedback she received because it helped her make her project a reality. When asked to clarify, she explained:

> What I liked about the teachers and also the other groups is they weren't like, 'No, that idea's not going to work. It's dumb. It's not going to work.' They were like, 'That idea could work if we had better technology. But what if you tweaked it this way?' So they kept our idea in our world, but changed it to make it be able to actually come to life.

Although students acknowledged personal growth as a result of exposure to others' unique perspectives, they also described some significant challenges related to exploring and acknowledging these perspectives. Eight of the fifteen interviewees reported challenging aspects to exploring multiple perspectives. First, while students may have learned how to acknowledge multiple perspectives, they found it difficult to incorporate them all as they worked to identify a solution to their group's problem. Indeed, they often discovered that there was obviously no way to incorporate everyone's perspective, and the challenge therein lied in determining which perspective was the most valuable to the current situation and how to communicate with one another effectively enough to agree on the issue.

Students also found it very difficult to develop an empathetic perspective of their target audience members, particularly if those people were significantly different from themselves. One challenging aspect of this was actually talking with members of the target audience. Students struggled with how to ask the right questions about sensitive topics and how to find members of the target audience to actually speak with to gain their perspective.

Another frustrating aspect of exposure to multiple perspectives was that students did not know how to reconcile the differing opinions they received from various people who critiqued their project and gave them feedback. Sometimes students reported that the members of the implementation team each provided a unique perspective on their group's project and had differing suggestions about how to improve upon their existing work. While students sometimes found it challenging to explore and incorporate the perspectives of other people they worked with throughout the project, they ultimately discovered that those other perspectives were valuable and beneficial in helping build a stronger final solution. Further, their own perspective was broadened as a result of the work they did.

Time.

Time was also a significant challenge to many of the students. Nine students discussed aspects of time that impacted their work. First, many students noted that there was not enough class time dedicated to the work they needed to get done. By the time all students arrived to the forum and received instructions about the goals for the day, a significant portion of class time had already passed. Then, students needed to spend time communicating within their group to determine their plan of action. Jasmine expressed frustration that she did not find enough time during workshop sessions to clarify all of her questions before working independently on her homework for the week: "I just had questions and then we ran out of time and it was so stressful. And [the teachers] were like, 'Oh, by the way you have this homework.' And then you didn't really know how to do it."

This frustration with an insufficient amount of class time connects to another aspect of time that made the work challenging for students: the project itself was simply more time consuming than other types of work they had done. Students spent a significant amount of time over the first several weeks of the project just framing the problem and conducting research to understand it in more depth. They did not acknowledge the value in the work they conducted at this phase and felt discouraged that they were not making any visible progress. Jasmine described the frustration she felt at the beginning of the project when she and her team mates were spending a lot of time on formulating the problem: “Well first of all, it took us a long time to get it narrowed down. So we really didn’t know what to research. And, it was just a lot of different web sites you have to go on. It was a lot of time. It was very time consuming.”

Other students perceived the time challenges to be more related to the schedule of the overall project over the span of eighteen weeks. They felt that it would have been much more effective if the project had not been spread out over so much time. Instead, they wished that the length of time the project spanned had been reduced to just a few weeks with many more meetings per week. Chrissy clearly described her frustration in this regard, and her sentiments echo those of many students:

> We only got an hour and some minutes doing…in the forum…. We didn’t exactly have enough time. Every day that we got together, we didn’t exactly…we had to focus on what we did last week, which took about 20 minutes to figure out where we should start off, and then we just couldn’t I guess get a lot of stuff done in that time.

Finally, students acknowledge that managing their overall time to make sure the project was fully complete by the day of their public presentation was difficult. Even though students were given the date of the Design Faire presentation at the local science museum during the first session, they found it difficult to manage their time because it was their own responsibility to set and meet intermediary deadlines to keep the project on track. Brittany communicated what she learned about time management in this way: “I guess if you want to get it done you’ve got to stick to it and you’ve got to think about it. Or in the end it’s not going to be completely finished. Because I didn’t think that we…we could have done better with ours. And so we really should have been more into it and worked harder on it and worked together on it."

Learning.

Another significant theme that appeared in nine of the students' interviews is learning. It's not often that students identify learning as a benefit of any educational environment, so the simple fact that students indicated learning gains as a benefit of the process is a benefit indeed. Students recognized that they learned not only detailed information about the problems they chose to solve but also many things not related to their topic. Some of the learning was academic. Connor, for example, reminded me that he definitely learned how to use PowerPoint and Microsoft Word, and Jasmine pointed out that she learned quite a bit about life in Africa as she investigated issues related to clean drinking water with her team members.

Other learning gains were more attitudinal in nature. Students reported learning how to become better people, how to care more about society, how problems impact people, what we take for granted, and what different people go through. They also noted that they learned information from other teams' projects even though they had not personally researched the subject. Erica explained that she perceived that all of the students who participated in the experience learned that "we didn't know as much as we thought we did. And it really opened our eyes to see that we're fortunate, we're more fortunate than other students are, and that we kind of take for granted all of the stuff that we have." She noted that she and her classmates "really started caring more about our society and the issues that are happening…. We knew stuff was wrong in our society, but we really, we grasped how…not bad it was, but how it really affects people." These statements illustrate that the learning environment fostered a sense of civic engagement and even civic responsibility in many students.

Motivation

A final, less prominent theme that is nonetheless quite important is motivation. Five of the fifteen students interviewed described maintaining intrinsic motivation as a skill they gained and benefitted from as a result of this project. These students explained that, although they felt frustration at various points in the process, the final result turned out as well as or better than they had expected. They acknowledged that they had to keep pressing on even when things got tough and, because they didn't give up, they were rewarded in the end. Aimee's comments summarize students' perspectives in this regard: "If you have challenges along the way and stuff, if you work through it, then it will all turn out okay. Just don't give up and it will work. Yeah, I think that's the main thing that was perceived from it."

The preceding sections clearly indicate that students perceived a variety of benefits and challenges to the learning environment in which they participated. Data collected in the midst of implementation from all fifty participating students also supports students' perceptions of the benefits and challenges identified herein. Near the mid-point of implementation, the students were each asked to reflect on the process so far and to describe, in their own words, not only what they were trying to accomplish but also what the most challenging and most interesting aspects were. Table 6 summarizes responses from all fifty student participants about the benefits and challenges they identified at that time.

Theme		**Sample Student Responses**
Benefits	Collaboration	• Getting to work with our peers and see the different sides of things and listening to their ideas and actually making a difference in this world so our kids can have a better life and learning about the problems and helping people • Getting along with my teammates • Getting to work with people I've never worked with • Working with my team • Getting to work together on a hard topic
	Multiple Perspectives	• The ideas people have come up with • Hearing different ideas for the invention

		• Hearing all the crazy ideas of my group on what we could do • Hearing everybody's ideas and how we might be able to join our ideas to make a great idea
	Learning	• Learning new things about the community • Finding research that makes me care a little • The research and the stuff we have found out • Learning new things about the topic
	Persistence	• The fact that we've had to try over and over again • Watching our progress and our plan grow
	Other	• I'm not really into science which it is about but I think that it is a good project to do with 8th graders • I enjoy reaching outside my comfort zone and doing a higher level thinking project that will help many people • The most interesting is actually being able to help people with these problems • The design process • Doing the storyboarding • We are trying to solve an actual problem
Challenges	Thinking	• Coming up with the right/good idea • Coming up with a solution to the problem • Trying to understand what we need to do to accomplish what we need to
	Collaboration	• Working in a group I don't like • Arguing because we have different ideas • Getting along with members in my group and trying to agree on one idea
	Time Management	• Learning how to manage time • Trying to get everything done in the hour that we have
	Multiple Perspectives	• Getting our knowledge from [target audience]
	Communication	• Listening to others
	Other	• Trying to get everything together. We will try to get people's attention but I don't know if it will work • Doing the storyboard • I really can't get into [my topic], I didn't want to do it. It wasn't my first or second choice, so I really am not interested • Planning the final project • Trying to see whether our solution will make a difference and what the effects will be • Deciding what our plan is • Our topic/project • Our ideas getting dropped • Trying to get this project moving. It feels like all we ever do is write and not really get anything done

Table 7: Summary of Students' Perceptions of the Most Interesting and Challenging Aspects of the Learning Environment, Mid-Term
(*all fifty students' responses summarized*)

In summarizing the students' feedback about the benefits and challenges of this learning experience, students clearly felt that collaboration, although challenging, ultimately taught them skills that they perceived as beneficial. Similarly, nearly all students identified the difficult types of thinking they had to do as a challenging aspect of the curriculum; however, in the end, they also said that the things they learned as a result of that critical thinking were a benefit of the project. The time constraints and the amount of time it took to do the work required contributed to the challenges they faced as they worked, but students also found motivation to push through those challenges because of the value they found in doing real work that prepared them for their futures and made a difference in the world.

Cross-Case Comparison

While students and teachers agreed on some of the benefits and challenges of the environment, there was clearly a distinction between what students perceived as challenges versus what teachers perceived as challenges. Analyzing these similarities and differences more closely, it becomes apparent that the teachers' concerns were primarily related to the methodological aspects of design-based learning: time, ambiguity, motivation, pedagogy, assessment, and support. The characteristics that students perceived as significant, on the other hand, are exactly the kinds of challenges that teachers are encouraged to facilitate in their learning environments: critical thinking, real world experience, communication, collaboration, exploring multiple perspectives, and time management. These differences in the students' and teachers' perceptions are not only to be expected but also meaningful in terms of what we can deduce about design-based learning environments. In essence, the message that comes from the data is that design-based learning is indeed hard for both students and teachers, but the benefits to each population make the process a challenge that is worth undertaking. In the following sections, the results are compared across cases to highlight the similarities and differences among students' and teachers' perceptions.

The students and teachers all found beneficial and challenging aspects to the design-based learning environment. While some of the themes presented in the preceding sections are unique to the cases in which they were explored, the data also revealed some common perceptions among students and teachers about the benefits and challenges of the learning environment. Table 8 summarizes the similarities among and differences between the themes across all three cases and shows which were beneficial and which were challenging.

When comparing the students' versus the teachers' perceptions, it is not unreasonable to expect differences. After all, each of these audiences ultimately has a unique goal with regard to educational objectives. Clearly, from looking at this data, there are some distinct differences between the teachers' and students' perspectives. The teachers generally agreed with one another about several benefits, but their perceptions did not correlate to the students' perceptions. Each case also had unique perceptions about the challenges of the learning environment. These similarities and differences among the cases are described in the sections that follow.

	BENEFITS									**CHALLENGES**										
	Crtitical Thinking	Real-World Experience	Communication	Collaboration	Multiple Perspectives	Transdisciplinarity	Pedagogy	Motivating	Learning	Critical Thinking	Real-World Experience	Communication	Collaboration	Multiple Perspectives	Time	Ambiguity	Motivation	Pedagogy	Assessment	Support
Case 1: Meredith	X	X	X			X	X						X		X	X	X			

Case 2: Sandra	X	X	X	X		X	X								X		X	X	X	X
Case 3: Students		X	X	X	X			X	X	X	X	X	X	X	X					

Table 8: Cross-Case Comparison of Benefits and Challenges by Theme

Similarities.

Real-world experience, communication, and time.

Meredith, Sandra, and the students all agreed that the real-world nature of the learning environment was beneficial. They consistently noted that the opportunity to design a solution to a real problem in their immediate world gave them valuable experience that prepared them for the kind of work they will do in the future. Furthermore, they also agreed that the experience they gained communicating with a variety of audiences and in a variety of formats was valuable practice. Students learned valuable skills as they presented to their peers, their teachers, school administrators, university faculty, and the general public. They also practiced how to communicate their ideas orally and visually as well as through text. All participants also clearly asserted that time was a challenging aspect of this environment also. Both the teachers and the students agreed that the length of the project was too expanded. Instead, they believed that it should have been implemented over the span of just a few weeks. This condensation would have helped everyone maintain focus without having to utilize valuable weekly time to re-assess team progress before moving forward with the next steps.

Critical thinking, transdisciplinarity, and pedagogy.

Although students and teachers only agreed on the benefits and challenges described above, it is interesting to also recognize that the two teachers agreed on nearly everything about the beneficial aspects of the learning environment. In addition to real-world experience and communication, which the students corroborated as beneficial, Meredith and Sandra also found the learning environment to be beneficial to students in other ways. First, it fostered students' critical thinking skills because it challenged them to think in new ways and push themselves in different directions as they made their own choices about their project and its solution, as they iterated, and as they utilized trial and error. The environment was also beneficial, according to the teachers, because of its transdisciplinary nature. Students explored a breadth of topics, from school bullying to clean water in Africa, and they utilized a broad range of skills from differing disciplines as they designed their solutions. Finally, Meredith and Sandra also found the environment to be personally beneficial to their own pedagogical knowledge and practice. Meredith asserted that the implementation helped strengthen her own design skills as she evaluated her own pedagogical decisions and determined how best to provide scaffolding to her students. Sandra found that she gained a new respect for her students as she relinquished control over the classroom environment and allowed students to make decisions on their own. Although this was a challenging aspect of the project for her, the outcome proved rewarding.

Differences.

The perceived challenges of design-based learning are clearly divergent across all three cases in this study. Even though all participants agreed that time was a significant challenge, they agreed on very little else. While the teachers both agreed that motivation was a challenging aspect of the environment, students instead reported motivation as a beneficial feature. Teachers found it challenging to motivate students to persist in the face of ambiguity and maintain their focus and energy toward the project. Further, Meredith noted that she found it difficult to motivate students to explore multiple ideas and solutions. Students, on the other hand, reported their sense of intrinsic motivation as a beneficial feature.

Students found benefit to the environment in a variety of other ways as well. They learned to speak more effectively and communicate their ideas in multiple ways to a variety of audiences. They built relationships with new people and learned to work effectively on a team with people who possess a diverse range of skills. Working with a diverse range of people also taught them the value of others' perspectives. They discovered how to empathize and realized that their own perspectives changed as a result of exposure to other thought processes. The real-world nature of the project gave students pride in their work. They valued the opportunity to make a real difference with regard to a problem in their immediate world, and they perceived their work as the type of important work that is normally reserved for adults and college students. Further, they gained a respect for how problems get solved in the real world and thus felt more prepared for the work they will do in their future.

The critical thinking aspect of the learning environment was wholly challenging to the students. They reported difficulty narrowing the focus of their project, and they also had a hard time coming up with a meaningful and feasible solution among all of the potential solutions they identified. Filtering through large amounts of information to determine what portion of the information was relevant made the process difficult as well. It is also interesting to note that students identified many of the benefits of the learning environment as challenges as well – a trend that did not present itself in the teachers' data.

Meredith and Sandra each identified some unique challenges as well. The ambiguous nature of the learning environment was a challenge for students, according to Meredith. She reported that students found it difficult tolerate the absence of a single, correct solution to their problem and they hesitated to risk failure as they tried to find a solution. It was difficult for her to support her students during these times of ambiguity. Sandra struggled with how to effectively assess her students' progress and learning gains while simultaneously maintaining the authentic nature of the learning environment. Further, she noted that administrative support for teachers who want to implement design-based learning is a significant challenge that would have to be addressed in order for wide-scale adoption of such a pedagogy.

Summary

The information presented in this chapter has revealed what the students and teachers who participated in the study perceived to be the benefits and challenges of the learning environment. The teachers and students all perceived critical thinking, real-world experience, communication, collaboration, motivation, and time to be factors that had a meaningful impact. Additional factors that appeared in the data included exposure to multiple perspectives, transdisciplinarity, pedagogy, ambiguity, learning, and support. Interestingly, the students perceived many of these factors to be both beneficial and challenging. Furthermore, the teachers and students each identified some unique perspectives of the benefits and challenges. The similarities and differences across these cases have the potential to reveal many lessons about how to best meet teachers' and students' needs when planning design-based learning environments. The following chapter first discusses themes across the three cases and the meaning of the information. It concludes with recommendations for teachers and instructional designers who may want to implement similar learning environments in the future.

Chapter 5: Discussion

The purpose of this study was to investigate what students and teachers perceived to be the benefits and challenges of design-based learning as implemented in this specific environment. I utilized a multiple case study methodology to explore the perspectives of three unique cases: (1) the English teacher, (2) the social studies teacher, and (3) the students. While the findings of the study are unique to the context of the investigation, the themes that emerged through coding and analysis of the data may be of use to other researchers and educators with an interest in learning more about design-based learning in K-12 settings.

This chapter presents a discussion of the themes that arose and how they relate to the overarching message derived through analysis of the data. It concludes with recommendations for future implementations of design-based learning with similar audiences. The assertions and recommendations made herein are based on the knowledge I gained through the literature review and analysis of the data collected for the study.

Overarching Messages

Ultimately, the results of this investigation revealed that while there are significant challenges of which to be aware and which teachers and instructional designers should consider when designing instruction, the benefits to teachers and students alike are undeniable. While teachers and students, when considered as individual cases within the study, struggled with unique challenges based on their perspectives and experiences, they also agreed on some of the challenging aspects. Similarly, while they identified benefits that were unique, they also found common benefits. Collectively, their perceptions provide valuable insights into the aspects of design-based learning that educators and instructional designers should consider closely during planning in order to minimize the challenging aspects that can lead to less than optimal conditions and capitalize on the benefits of this teaching method. The findings presented thus far revealed several themes that, considered together, translate to an overarching message that will be used a lens through which to discuss the information in the following sections: *design-based learning is hard, but it's worth it.* This message contains several points:

1. Design-based learning takes a lot of time, but the investment has a positive impact on student motivation and learning outcomes.
2. Design-based learning requires teamwork and communicating with a variety of audiences, but students develop communication and collaboration skills as well as the ability to appreciate a diverse range of skills and perspectives.
3. Design-based learning is ambiguous and unpredictable, but students gain real-world experience and critical thinking skills in a transdisciplinary environment.
4. Design-based learning poses real pedagogical challenges, but it also results in benefits to the teachers involved.

Table 10 illustrates how the themes that arose when coding the data relate to the overarching message, and the following sections provide a discussion of each as well as recommendations for future, similar implementations of design-based learning.

1. Design-based learning takes a lot of time, but the investment has a positive impact on student motivation and learning outcomes.	• Motivation • Learning
2. Design-based learning requires teamwork and communicating with a variety of audiences, but students develop communication and collaboration skills as well as the ability to appreciate a diverse range of skills and perspectives.	• Communication • Collaboration • Multiple Perspectives
3. Design-based learning is ambiguous and unpredictable, but students gain real-world experience and critical thinking skills in a transdisciplinary environment.	• Transdisciplinary • Real-world • Critical Thinking • Ambiguity

4. Design-based learning poses real pedagogical challenges, but it also results in benefits to the teachers involved.	• Assessment • Support

Table 9: Categorization of Themes from the Data

1. **Design-based learning takes a lot of time, but the investment has a positive impact on student motivation and learning outcomes.**

The only commonly agreed upon challenge across all of the participants in this investigation was time, so its significance to both teachers and students is apparent. Time was an unsurprising challenge based on the literature review about potential challenges of design-based learning. Students generally perceive design work itself to be time consuming (Carroll et al., 2010), and teachers harbor concerns about the time investment they must commit to in order to implement a design-based learning project (Davis et al., 1997). Indeed, some of the students who participated in post-implementation interviews discussed the extensive time it took them to frame the problem, to conduct research, and/or to build their prototype. The teachers reported similar concerns about the time investment. They both felt that this was a challenging project because it required them to do more work outside of class time to prepare for the next session. These findings are consistent with the literature and must be considered whenever one considers implementing a design-based learning environment. Barron and Darling-Hammond (2008) reminded readers that design-based learning environments must be carefully planned to include adequate time for the extended student inquiry and the open-ended, iterative nature of design.

While some of the reports about the challenges of time in the current investigation indeed related to the time commitment as described above, it is also evident that some of the challenges related to time that participants in this study reported had more to do with the manner of implementation. Since we spread out the meetings over an eighteen-week span, both the students and teachers felt that the project was too long. The planning team utilized this long range plan in an attempt to mitigate the challenges that the participating teachers had expressed about having to dedicate so much class time to the project; however, it seems that this strategy was unsuccessful. Both students and teachers recommended that the project be completed in a much shorter time frame – perhaps three weeks – in future iterations. Davis et al. (1997) also suggest that teachers search for ways to incorporate larger blocks of time into their schedule to allow students ample time to complete design tasks. While the implementation team in the current study initially planned 90 minutes sessions once per week, this time was diminished by the need to re-focus student teams at the beginning of each session. Indeed, this illustrates the crucial need for careful planning to include adequate time for all of the tasks that must be accomplished.

Learning and motivation.

Noweski et al. (2012) described the synthesis process of the design cycle, the point at which design teams must consolidate all of the information they have discovered to narrow the focus of the project, as

> the first moment of truth where the team that enjoyed diverging over a broad mass of information, exploration and solution spaces has to now converge to a point of view that has the power to give them the necessary drive for the next diverging session…. This is often the hardest milestone in the process and proceeds with a lot of discussion and an abrupt loss of motivation. Teams that manage to get out of this abstract bottleneck still united as a team, with a shared and clear understanding of the challenge to work on, are usually the ones that will succeed.” (p. 83).

Students and teachers certainly described a point at which they stalled in the process because they did not know what to do. They reported frustration over the amount of time they spent doing research to help narrow the focus of the problem without seeing any results. The implementation team had to support the students and let them know they were indeed making progress, even if they could not see it; however, in the end, most teams ultimately did see progress and found the motivation to push through to the final solution. Despite the significant time investment that both teachers and students committed to the project, their post-implementation perceptions indicate that they also found the project to be worthwhile. Once students invested the time, they realized that the environment had been motivating enough to keep them going through to the end, and they learned a lot – not only about their own topic, but also about others teams' topics. Students ultimately expressed great pride in the work that they did and in their final products.

2. **Design-based learning requires teamwork and communicating with a variety of audiences, but students develop communication and collaboration skills as well as the ability to appreciate a diverse range of skills and perspectives.**

Design-based learning environments involve working on a team, and there are inherent challenges associated with teamwork. It also involves communicating with a variety of audiences – including teammates, target audience members, and members of a critique panel. The challenges of working with others include collaborating, communicating, and exploring multiple perspectives. Effective collaborative groups must tackle all of these challenges to be successful.

Collaboration.

Waite and Davis (2006) posited that 21st century skills can be fostered by implementing collaboration in the classroom. Through collaboration, they argue, students develop critical thinking skills that help them understand the value of others' perspectives, establish productive habits of communication with group members, and build interdependent working relationships with others. Similarly, Barron and Darling-Hammond (2008) noted that "the focus of research has gone beyond the practical benefits of collaboration for individual learning to recognize the importance of helping children learn to collaborate as necessary preparation for all kinds of work." While these sentiments demonstrate the need for collaboration in classrooms, the challenges associated with collaboration are well documented. Students often perceive collaboration negatively when they are required to do work outside of class (Snyder, 2010), when team members do not contribute an equal share of the work (Carroll et al., 2010), and because they have difficulty determining how to work with team members who have different work habits (Barron & Darling-Hammond, 2008).

One strategy for mitigating the challenges of collaboration that is quite intrinsic to a design culture is to help students learn to acknowledge each other's unique abilities and capitalize on them. Barron and Darling-Hammond (2008) pointed out that design challenges often dictate "the need for collaboration and for specific roles for different students, providing them with the opportunity to become 'experts' in a particular area" (p. 7). The implementation team in the current investigation utilized this strategy successfully when we collectively recognized that some students were feeling frustration over the imbalance of work across their group. We assigned four roles on each team: a project manager, a researcher, a builder (prototyper), and a presentation manager. These roles helped us ensure that each student assumed responsibility for a specific task that needed to be accomplished, and students and teachers both reported in their post-implementation interviews that they perceived this strategy to improve the group dynamics. Sandra, for example, stated, "some members weren't pulling their weight, some members were doing it all. To combat that, Teri came up with assigning certain roles, and that was very effective."

Collaboration can also be difficult because team members do not know one another and are unfamiliar with the different work habits group members possess (Barron & Darlin-Hammond, 2008). Successful collaborative groups are based on a foundation of trust and respect (Johnson & Johnson, 2008), thus teachers should implement activities to foster such relationships in the group to ensure successful collaboration. That the students and teachers in this study acknowledged collaboration as a difficult aspect of the project is also unsurprising, but we utilized specific strategies to mitigate the challenge. To foster successful collaboration in the current investigation, the teachers and researcher conducted activities for team members to get to know one another and build an identity together as a team. Each group came up with a team name and designed posters to "advertise" their team members and their skills early on in the semester. Those team names became how we referred to them during class time, and we utilized the team members' individual skills as the opportunity to do so presented itself throughout the semester.

Communication.

The development of communication skills has been documented as a potential benefit of design-based learning environment. Davis et al. (1997) asserted that one reason teachers who have utilized design-based learning support it is because it fosters students interpersonal and communication skills. Doppelt et al. (2008) and Rowland (1993) also discovered that students develop communication skills as they work through the design process. In the current study, communication was also a clearly significant factor for all participants. Teachers and the students who participated in interviews all noted that the students practiced and gained valuable communication skills as a result of participating in the process. What is notable in the findings of this research is that teachers and students pointed to multiple aspects of communication. The data revealed that students gained both verbal and nonverbal communication skills as well as knowledge about how to communicate with a variety of audiences. Also notable is that students reported communication as both a benefit *and* a challenge. During the implementation, students experienced frustration over the challenges of communication. As they discovered effective methods over the course of the semester, their perceptions shifted and they came to realize that they had learned some effective strategies as a result of their hard work.

Multiple perspectives.

Davis et al. (1997) explained that design challenges provide an opportunity for teachers to “nurture students’ collaborative skills…. Many teachers report that the complexity of design problems allows children with different skills and different ‘ways of knowing’ to contribute at different moments in the process and to present a variety of viewpoints throughout the process” (p.33). Interestingly, it was not the teachers who reported this benefit in the current study but rather the students. They acknowledged that they learned to value their peers’ perspectives and skills, and that their project was ultimately stronger because of the multiple perspectives that contributed to the product.

One of the core tenets of modern learning theory is that learners construct knowledge in a social environment through interaction with others who have varying levels and types of knowledge (Vygotsky, 1974). Through these interactions, learners negotiate their understandings and build personally relevant bodies of knowledge that they can utilize in other situations. The findings in this study support the notion that students indeed constructed knowledge through interactions with the different audiences that they worked with. Through working with others that they did not know prior to this implementation, students discovered alternative ways of knowing and incorporated those into their own ways of knowledge when appropriate. In other words, they reported that they utilized and found benefit from the constructivist learning environment in which they worked.

While exposure to others' perspectives was a significant factor in the students' and teachers' reports, the participants also acknowledged that they appreciated that their own personal perspective was acknowledged during this process. Carroll et al. (2010) noted that "one of the goals for design in schools is to create a classroom climate where student voices are listened to so that they might they become more and more confident in their own ideas" (p. 48). Indeed, many of the participants who conducted post-implementation interviews discussed how the multiple voices that contributed to the project had a significant and positive impact on the final product.

In summary, students discovered through participation in this design-based learning environment that teamwork, although challenging, is a skill that they perceive to be a valuable asset. As students practiced the skills identified herein, they discovered that their ability to collaborate, to communicate effectively, to explore and appreciate others' perspectives, and to encourage one another to work hard to the end all proved to be beneficial in terms of producing a final product of which their team could be proud.

3. **Design-based learning is ambiguous and unpredictable, but students gain real-world experience and critical thinking skills in a transdisciplinary environment.**

Cross (2006) explained that "designing is a process of pattern synthesis, rather than pattern recognition. The solution is not simply lying there among the data, like the dog among the spots in the well known perceptual puzzle; it has to be actively constructed by the designer's own efforts" (p. 8). This is the nature of ill-structured problem solving. There is not a single solution, and the ambiguity of design-based learning environments can sometimes be overwhelming for students (McDonnell, 2012). The themes of critical thinking, real-world experience, and transdisciplinary learning are all relevant to the nature of ill-structured problems, as explained below. As students and teachers experienced these aspects of the learning environment, they found that the challenges resulted in ultimate benefits.

Critical thinking.

Carroll et al. (2010) asserted that "design thinking has an impact on the ways that students engage in the learning process. It challenges them to think in new ways" (p. 51). Certainly the teachers and students agreed that the learning environment challenged students to think in new ways, and their interviews revealed several aspects of critical thinking. First, students referred to "narrowing the topic" repeatedly and labeled it as one of the most difficult aspects of the entire process. Indeed, narrowing the topic is frequently cited as a challenging aspect of the design process. Many studies have emphasized that those who are new to the design process have a difficult time defining the problem and take too long to move into the solution space (e.g., Atman, et al., 1999; Christiaans & Dorst, 1992).

Students also identified filtering information and finding a meaningful solution as challenges of the process. Each of these skills are components of the reflective judgment component of critical thinking, which involves analysis, synthesis, and evaluation of information (Combs, Cennamo, & Newbill, 2009). Meredith also referred to students practicing analysis and evaluation as they developed questions for their target audience. Similarly, Sandra described how students had to think for themselves and had control over their own learning. Since the implementation team could not scaffold each of the twelve groups individually as they worked through the different phases of the design process, certainly the teams did have to think for themselves. As they made decisions about their project, they practiced critical thinking skills that they will use in a multitude of environments in the future.

While teachers perceived critical thinking to be a benefit of the learning environment, students perceived it as both a challenge *and* a benefit. Perhaps this dichotomy in the students' perspective is representative of an attitudinal shift. That is, while students recognized the challenge and even admitted at times that they did not like it, the result of their work helped them develop a positive perspective on the value of hard work. Combs, Cennamo, and Newbill (2009) identify cognitive restructuring as a critical thinking skill that encompasses a student's ability to perceive their performance and abilities in a positive light. Students' positive verbalization of their performance and abilities during interviews, then, is an indication of their critical thinking skills.

Real-world experience.

Nicholl et al. (2013) noted that "for Dewey (and others) authentic experiences are fundamental to learning" (p. 932). The data revealed that students and teachers all acknowledged that the design challenges that students worked to solve were authentic and related to a problem in the students' immediate world, and most of the students who participated in interviews described their pleasure in participating on a project that had a real impact. Carroll et al. (2010) reported a similar finding with students: "when students see that they can have an impact, they often begin to look at the world differently and may see new opportunities and new possibilities around them" (p. 46). Students in the current investigation were sometimes surprised that they were actually able to accomplish the task that was laid out, and the interview data support the notion that they will perceive future tasks differently because of the experience they gained through this project.

Much of the research on design-based learning also indicates that the methodology helps students identify connections between what they do in school and what happens in real life outside the school walls (Davis, 2004, Davis et al., 1997; Razzouk & Shute, 2012). Indeed, not only did the students find value in participating in a project that had a real-world application or significance, they also reported that they felt as if they were doing work that is normally saved for older or more mature people like college students or adults. This sentiment indicates that the students perceived their work to be more like what people do once they have graduated from high school.

Transdisciplinary learning.

Wall and Shankar (2008) reported that working in an environment that requires transdisciplinary knowledge results in a variety of benefits, which include an increased respect for the skills and knowledge of others, a blurring of the boundaries between disciplines, and the exploration of factors that impact human health and well being. As students worked to identify solutions to the real-world problems that they identified in this study, they indeed explored topics related to the health and well being of the people in their world. They studied difficult topics such as obesity, bullying, discrimination, and suicide, to name a few. As they explored their topics, they discovered multiple perspectives on these issues and learned that each of those perspectives held value with regard to the potential solution. Furthermore, they discovered that they needed the knowledge that others possessed but they themselves did not.

The teachers' perceptions that the transdisciplinary nature of the learning environment was perhaps the most rewarding finding about this theme. Meredith and Sandra both acknowledged that design-based learning environments enable one to cover a breadth of topics and a broad range of skills in one project. While integration of content area knowledge can be a challenge in design-based learning and teachers must carefully plan content integration to ensure knowledge gains (Carroll et al., 2010), it was rewarding to observe that teachers not only acknowledged the potential transdisciplinarity but also see that potential as a benefit of the methodology.

In summary, the students and teachers all perceived the ill-structured and open-ended nature of the learning environment to be challenging. As they utilized critical thinking skills to navigate the challenges, they discovered that they were practicing the skills that people use outside of school walls. Part of this realization came from the fact that they were solving problems that were indeed real and relevant in their immediate worlds. As students explored the problems they identified, they also reported that they learned and utilized knowledge from a variety of domains to solve the problem. All of these factors combined to create an ultimately positive perspective on the ill-structured nature of design-based learning.

4. **Design-based learning poses real pedagogical challenges, but it also results in benefits to the teachers involved.**

Implementation of design-based learning can be challenging, particularly for teachers who are unfamiliar with the design process themselves. As Davis et al. (1997) highlighted:

> Design-based approaches force teachers to really think about what they are doing. For many teachers, it is the first time they are building from the ground up, not from surface material down. Teachers don't generally begin from nothing. They deal with boxes of curriculum materials and prepared content… Design forces them to go back and ask why they are trying to do something. It forces them to

> function as creators and authors, which teachers rarely do without a design education. (p. 95)

In order to implement and sustain design-based teaching and learning, they argue, teachers need support – not only in the form of training, but also in the form of resources to help them make the pedagogical shift to the role of a facilitator in a transdisciplinary environment. Further, while assessing what students know and are able to do is of importance in all learning environments, teachers who recognize and incorporate authentic, formative assessments into their programs help students build "internal systems of accountability… and… nurture the student's desire to achieve high standards" (p. 30).

Support.

Rotherham & Willingham (2009) emphasized that support for teachers is a crucial component that must be considered if real change is to occur:

> For change to move beyond administrators' offices and penetrate classrooms, we must understand that professional development is a massive undertaking…What teachers need is much more robust training and support than they receive today, including specific lesson plans that deal with the high cognitive demands and potential classroom management problems of using student centered methods (p.20).

Davis et al. (1997) also found administrative support to be a widely agreed-upon challenge according to teachers and administrators who have utilized design-based learning in K-12 classrooms. Sandra certainly echoed this notion and suggested that teachers need training during the summer when school is not in session so that they have time to learn and plan without the pressures of the school year weighing them down.

Pedagogy.

Carroll et al. (2010) reminded readers that design projects are beneficial to teachers as well as students. As teachers learn new ways of thinking through exposure to design methods, they incorporate those ways of thinking into their teaching. Davis et al. (1997) echoed this sentiment and added that design-based learning is a strategy for excellent teaching that transforms the teacher from authority to facilitator. Both Meredith and Sandra demonstrated a shift to the role of facilitator during the implementation. The shift occurred almost naturally since they needed to support their students' progress but did not have all of the necessary resources to do so. Instead of telling students what they needed to know or providing them with the resources they needed, the teachers modeled their own learning processes to students as they asked them questions about their project and worked with teams to determine how to move their projects forward. As a result of this work, both teachers also acknowledged that their perceptions about students' abilities changed.

Assessment.

The assessment of student learning gains is a well-documented challenge of design-based learning (Carroll et al., 2010; Davis et al., 1997; Razzouk & Shute, 2012), perhaps because educators are interested in content learning gains as well as gains in 21st century skills, which are difficult costly to assess effectively (Rotherham & Willingham, 2009). Carroll et al. (2010) noted that subject area learning can be difficult to successfully incorporate in design-based learning, particularly if the students are unfamiliar with both the content area under investigation as well as design methods, and educators must plan strategically. Sandra was the only participant to directly mention assessment in her interview. She asserted that assessment is important because it permeates our society. We are all constantly being assessed – by our employers, by our teachers, by our peers – so the results of assessment are important to us.

I urged Sandra multiple times during the semester to consider the role of feedback in assessment. When designers present their ideas in front of an audience for critique, they use the feedback to learn what works and what does not (Carroll et al., 2010), or, in other words, to assess their progress. Critiques help designers identify where their gaps in knowledge are and how their ideas can be better communicated to target audiences (Dow et al., 2012). The implementation team utilized strategies to formalize the critiques. We created forms for members of the critique panel to fill out, we required the design teams to demonstrate how and why they utilized or disregarded their feedback, and we used the feedback forms as a formal assessment of students' progress (see Appendix B); however, even these formalized feedback forms did not satisfy Sandra's need for assessment. Further, while the students did not directly mention feedback, they certainly alluded to the fact that sometimes it was challenging because they were not exactly sure how they were doing. The message to be gained from this experience is that researchers and educators who plan to implement similar design-based learning environments would be wise to identify and agree upon assessment issues prior to implementation. They should determine not only which skills and content knowledge comprise the learning goals for the project but also how each of those will be assessed. Finally, they should be clear with students about how the learning environment will differ from other more traditional learning environments and how they will be assessed on their process and products.

Limitations

It is important to note that the results reported herein are those of a case study of a very specific environment that does not generalize to other populations. Although the planning and implementation teams utilized a pedagogical model for teaching design to guide our processes at each stage, the decisions we made about scheduling, content, grouping, and even presentation all impacted the learning environment. While the students' and teachers' perceptions of the benefits and challenges of the environment are unique to this study, they illuminate some important considerations that may inform design decisions for similar learning environments in the future.

Although readers cannot make direct generalizations from this research, they may generalize the results of this study through a process called naturalistic generalization. Stake (1995) described naturalistic generalization as a process through which readers of case study research combine their direct personal experiences with the experiences that they gather vicariously through descriptive case studies. The combination of personal and vicarious experiences allows the reader to self-generate knowledge that helps them to transfer that knowledge to their own environments with unique populations. Stake emphasized that case study research should "attend to the matters that personal curiosity dictates. A narrative account, a story, a chronological presentation, personalistic description, emphasis on time and place provide rich ingredients for vicarious experience" (p. 87). I have certainly attempted to include such components in this report.

Recommendations

I carefully analyzed what students and teachers who participated in this study perceived to be the benefits and challenges of the methodology. One of the goals of this research was to provide recommendations to teachers and instructional designers about how to mitigate the challenges and capitalize on the benefits of such a methodology. Such recommendations, it is hoped, will help to ensure future success with the methodology in K-12 classrooms. To mitigate the challenges and capitalize on the benefits that students and teachers identified in this study, the following recommendations are offered:

- Plan your project to span a concise and specific time frame;
- Meet frequently and for ample periods of time;
- Keep the scope small – only one design challenge per class;
- Identify the target audience ahead of time and ensure that there will be opportunities to collaborate with members of that audience;
- Identify objectives and plan assessments in advance;
- Implement strategies to ensure successful collaboration;
- Clarify the teacher's role as facilitator.

With regard to time frame, recall that teachers and students both commented that they feel the project took far too long to accomplish and that it should have been scheduled to span a more concise time frame. This time factor may have impacted other aspects of the environment, so research utilizing an alternative schedule may reveal new insights. Similarly, an instructional plan that includes more frequent meetings for longer periods of time may reveal additional information about the relationship between time factors and the perceived benefits and challenges of design-based learning.

All members of the implementation team agreed, upon completion of the project, that implementation would have been much more manageable if all students had been working on a similar topic. Since each of the twelve groups identified a unique and weighty problem to address, scaffolding each of the groups sufficiently was challenging. It is recommended that teachers and instructional designers who plan similar learning environments give each group the same design challenge. This strategy will also help with the recommendation to identify the target audience in advance. With only one audience to focus on, finding and collaborating with members of that audience will be a more manageable task.

It is also recommended that teachers and/or instructional designers work carefully to identify learning objectives – particularly content-related objectives – in advance and plan assessments for those objectives before implementation. This strategy will help ensure that the assessments are more authentic and in line with the nature of the other activities going on in the classroom. If formal tests of content knowledge cannot be avoided, consider where such assessments best fit into the flow of the design process.

It is always important to remember that successful collaboration is built on a foundation of trust and respect (Johnson & Johnson, 2008). When team members do not know one another well or have not worked together in the extensive manner that is required in design-based learning, implement activities at the beginning of the collaborative project to build team cohesion. As students get to know one another better and feel mutually invested in the outcome of their project, their collaborative experience will be more positive.

Finally, it is crucial that teachers understand how a design-based learning environment differs from a more traditional learning environment. Many teachers are used to a classroom in which the control of learning is in their power. Their job is to disseminate knowledge to their students. Design-based learning environments, on the other hand, transfer the control of learning to students. The teacher's role is to facilitate that learning experience by providing the scaffolding that students need to meet the learning goals they specify personally. For many teachers, this transfer of control can be challenging to acquiesce.

While these suggestions can never be implemented in an environment exactly the same at the one described herein, similar studies with other audiences or alternative pedagogical models for learning design would be beneficial. Also, based on Sandra's suggestion that the students involved in this study may have had difficulty maintaining motivation because of a lack of maturity level, another suggestion would be to implement a similar study with older students to see if the results differ. Such studies would contribute to the growing knowledge base about design-based learning and contribute more information for those who are interested in learning to use design-based methodologies in the K-12 classroom successfully.

Closing Thoughts

John Dewey once said, "Give the pupils something to do, not something to learn; and the doing is of such a nature as to demand thinking; learning naturally results." The findings in the current study are related to a project in which the implementation team gave the students something to do – not something to learn. Students' goals were ill-defined from the start, yet their comments during post-implementation interviews indicated that they learned significant lessons related to the skills needed in the 21st century. As students designed, they practiced communication, collaboration, and critical thinking. They learned to find and utilize knowledge that was necessary for solving the problem at hand, and they found value in the process after they survived the challenge.

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Appendix A:

Empathy/Define/Ideate Phase Individual Reflection Assignment

ICAT Homework (due Tuesday, November 6)
Answer the following questions and e-mail to [instructor's email] before 8:30 am on Tuesday, November 6. Your answers can be in the form of a word document, a power point, a video recording, or an audio recording. Talk to [your teacher] if you do not have access to e-mail.

Student Name: ___________________________________
Group Name: _____________________________________

Part I:
Last week 3 other groups listened as you stated your problem, three constraints, your solution and the resources you were planning to use as you continue to work on your project. They provided you written feedback on these items. Read their feedback.

1. React to the feedback from others. What do you think about what they said?

2. What did they bring up that you didn't think about before and you feel you need to now?

3. Will this change how you are attacking the problem? How can you change your idea/solution?

Part II:
Based on the presentations from last week, we are concerned that many of you are not keeping your target audience in mind. You are designing for people (someone in your immediate world). Do you understand who your target audience is?

1. Give a description of your target audience. Who is impacted by your topic? Who are you designing for?

2. Based on your empathy stage (the interviewing stage), what did you learn from your target audience? *****If you do not have an answer to #2, you need to find people and talk to them! This is the most important part. How can you design for people when you don't know how they are impacted or what they need? <u>You might think you know, but until you ask, you don't</u>. Do this before moving on to question #3.*******

3. How did what you learned from your target audience impact your decision for the solution to the problem?

4. Why is this solution important to your audience member? How is this meeting their needs?

<u>Part III:</u>

We want to hear your plan from each of you, individually. Some of you were very quiet in the presentations last week. Also, some of you were nervous and maybe what you wanted to say didn't come out as clearly as you had planned. Here's your chance to articulate what you are thinking for us.

1. Clearly state your problem. "How might we…"

2. List at least three constraints your solution has to meet. (***If you cannot measure whether or not your project meets these goals, then you have not identified the proper constraints. Let's talk about all of this Thursday.)***

3. Give a description of your solution.

4. Give a description of what your solution is going to look like in a science museum exhibit.

5. Don't forget your museum exhibit must meet the following constraints:

   a. How will it use a STEM (Science, Technology, Engineering or Math) topic?

   b. How will it make the world a better place?

   c. How will it be interactive (give the user at the museum something to do)?

Feel free to sketch out visually what your solution and/or your museum exhibit will look like for next Thursday's meeting. That will be the next step… story boarding.

Appendix B: Public Critique Rubric

	1	2	3	Comments
Problem Statement				
Team provides a clear statement of the problem they are trying to solve.	weak	fair	strong	
Description of target audience				
Team describes a typical person impacted by the problem.	weak	fair	strong	
Description of constraints				
Team provides a list of the constraints for their project.	weak	fair	strong	
Description of solution				
Team provides a description of the solution to the problem.	weak	fair	strong	
Group presentation				
Team communicates their project plan effectively using both pictures and words.	weak	fair	strong	
Presentation requirements				
Adhere to time constraints	weak	fair	strong	
Demonstrate confidence with presentation content	weak	fair	strong	
Additional Comments				
Please use the space to the right to provide additional comments about the strengths of the project.				
Please use the space to the right to provide additional comments about how the team might improve their project.				

Appendix C:

Final Preparation and Revision Feedback Form

SECOND SATURDAY SCIENCE: BETTER BY DESIGN FAIR

1. List your team members' names and the times they will be in attendance at the museum. ***The exhibit is from 10:00 a.m. – 2:00 p.m. on Saturday, February 9.***

Name:	**Time:**
____________________	____________________
____________________	____________________
____________________	____________________
____________________	____________________
____________________	____________________

2. Describe how your solution makes the world a better place.

____

____

____

3. Describe how your exhibit gives visitors something to do.

____

____

4. Identify what parts of your exhibit support good visual design.

____

____

5. Identify the STEM components of your project:

   Science: ____

   Technology: ____

   Engineering: ____

   Math: ____

6. Test your presentation that will be running on a computer. Does it run automatically, without anyone having to "click" through? (circle one) YES NO

   If "NO" then find someone to help you make it run automatically! Have them initial here: _______________

7. Visitors to your exhibit will want to know how the facts support your solution. In the space below, describe the facts you've used to support the solution you chose:

   ____

   ____

   ____

   ____

   ____

   ____

8. Visitors to your exhibit will want to know why the solution you chose is appropriate for your target audience. Describe this in the space below.

9. Identify (do not describe) the major phases of your design process: