A Framework for Design Theory and Methodology Research

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Abstract

The scholarly study of design continues to develop new knowledge through a variety of approaches. Some researchers examine how designers work, and many develop new methods to help designers do design tasks. Studying design is complex for many reasons. There are many domains in which design occurs, including all of the disciplines of engineering, architecture, and other fields. More significantly, humans design, and human behavior can be difficult to understand. Designers sometimes work alone and sometimes in a group or team. Designers experience design work in multiple ways. Design researchers have been exploring many different aspects of design and experimenting with many different approaches and generating a variety of different design theories. The focus on exploration, however, has meant that there has been less emphasis on exploiting previous research and creating an organized body of knowledge. Building a unified body of knowledge is a long-term challenge. This paper describes a proposed framework for design theory and methodology research. This framework, which is based on ideas from education research, does not specify specific topics or methodologies. Instead, it describes six different *research types*: (1) Foundational Research, (2) Early-Stage or Exploratory Research, (3) Design and Development Research, (4) Efficacy Research, (5) Effectiveness Research, and (6) Scale-up Research. Illustrating these types are examples based on a table design example. The paper explains how these six research types are related to each other and how, collectively, they serve to generate valid knowledge about design. The research types follow a logical sequence in which researchers develop basic knowledge, create design methods, and test design methods. Although the framework numbers the research types following this natural progression, it does not insist that researchers do or should work by rigidly following this sequence. These research types actually form a cycle of research that iterates through three "phases": description, explanation, and testing. In this cycle, researchers observe and describe a phenomenon, develop theories to explain the phenomenon and its interactions and effects, and test that theory against the phenomenon, and then, based on the results, refine their descriptions, revise their theories, and conduct more testing. Over time, the description of the phenomenon is improved (e.g., made more precise or more general), better explanations (theories) are found, and additional testing further demonstrates their correctness (or indicates their limitations). The proposed framework can show how different research studies are related to each other because they are the same research type or they fit into the progress of a design theory or the development of a design method. Thus, the proposed framework, while not a theory of design, can help researchers respond to the challenges of coordinating the different types of research needed to create useful design theories and build a unified body of knowledge. Future work is needed to analyze, test, and refine this framework so that it becomes truly useful to the design research community.

1. Introduction

The scholarly study of design continues to develop new knowledge through a variety of approaches. Some researchers examine how designers work, and many develop new methods to help designers do design tasks. Studying design is complex for many reasons. There are many domains in which design occurs, including all of the disciplines of engineering, architecture, and other fields. More significantly, humans design, and human behavior can be difficult to understand. Designers sometimes work alone and sometimes in a group or team. Designers experience design work in multiple ways (Daly et al., 2012): as evidence-based decision making, organized translation, personal synthesis, intentional progression, directed creative exploration, and freedom.

Therefore, it is not surprising that design research has been exploring many different aspects of design and experimenting with many different approaches. The focus on exploration, however, has meant that there has been less emphasis on exploiting previous research and creating an organized body of knowledge. Le Masson et al. (2013) described the lack of unity of the design theory field and the proliferation of different design theories.

This paper describes a proposed framework for design theory and methodology research. This framework, which is based on ideas from education research, does not specify specific topics or methodologies. Instead, it describes different research types and explains how they are related to each other and how, collectively, they serve to generate valid knowledge about design.

Because education, like design, is a complex human activity, and education research, like design research, is meant to yield methods that have a practical impact, it is reasonable to examine education research for ideas that can be applied to design research.

Of course, the research types described here cannot cover every possible type of design research.

2. Background: Education Research

The "Common Guidelines for Education Research and Development" is a report from the U.S. Department of Education (ED) and the National Science Foundation (IES/NSF, 2013). Hereafter we will call this report the "Common Guidelines." A committee of representatives from NSF and ED established these guidelines in order to improve "the quality, coherence, and pace of knowledge development in science, technology, engineering and mathematics (STEM) education," but the guidelines are applicable to other types of education research. It is important to note that this work considered research and development activities that sought "to increase learning." The committee defined different types of research, specified how they relate to each other, and identified the theoretical and empirical basis needed to justify each research type (IES/NSF, 2013). The Common Guidelines report documents the different types of research and explains how each type, when done correctly, contributes to generating evidence about how well instructional strategies increase student learning. In addition to helping NSF and ED make programmatic decisions, the Common Guidelines can help the scientific community write and review proposals and papers by describing the expectations for each type of research. The Common Guidelines describe six types of research as a "pipeline" of evidence that leads to evidence about the effectiveness of instructional strategies but acknowledges that research does not move in a strictly linear way.

3. Types of Research

The following sections list the six types of research described by the Common Guidelines. They describe how each type of research is relevant to the study of design. Illustrating these types are examples based on the table design example presented by Messac and Chen (2000).

First, we will list the six research types:

Research Type #1: Foundational Research
Research Type #2: Early-Stage or Exploratory Research
Research Type #3: Design and Development Research
Research Type #4: Efficacy Research
Research Type #5: Effectiveness Research
Research Type #6: Scale-up Research

Research Type #1: Foundational Research

Foundational research studies develop new knowledge about design, the activities that occur during design, and the organizations in which design occurs. These studies may test, develop, or refine theories of design and may develop innovative research methodologies.

Example: A researcher studies how a team divides the table design task into subproblems and, based on these observations, creates a theory that the organization of the design team mirrors the decomposition of the table into components (cf. Conway, 1968; Colfer and Baldwin, 2010).

Research Type #2: Early-Stage or Exploratory Research

Early-stage or exploratory research studies develop new knowledge about design by examining the relationships among important concepts in design theory and establishing correlations and other logical connections that could be used as the basis for a new design method. These studies are concerned with design outcomes such as the quality of a design solution or the resources spent to complete the design.

Example: A researchers collects data about how teams design a table, evaluates the quality of their solutions, and identifies correlations between the problem decomposition, the team's organization, the time required to design a table, and the quality of the table that is generated.

Research Type #3: Design and Development Research

Design and development research studies create new design methods that are meant to improve in a specific way some activity in the design process. These studies draw on existing theory and evidence to design the new methods. These studies define the measures that will be used to assess the design method and study of feasibility of implementing the design method. These studies may include some limited pilot testing while developing the new design method and may generate questions that motivate additional work to refine the relevant design theory.

Example: A researcher develops a table design tool for use by distributed teams and conducts some demonstrations to show that teams who are organized in a specific way can use it to design a table and to test the techniques for measuring design quality.

Research Type #4: Efficacy Research

Efficacy research studies test a design method under optimal conditions, and those using the design method may receive assistance. These studies may be limited to a single population. The developer of the method may be involved in implementation and evaluation. These studies should determine whether the design method can improve outcomes under such ideal conditions.

Example: The researcher (the table design tool developer) tests the table design tool using teams of engineering graduate students who are taking a design methods course taught by the researcher. The researcher collects data to determine whether the students who used the table design tool generated better tables than the students who did not use the table design tool.

Research Type #5: Effectiveness Research

Effectiveness research studies test a design method under typical conditions that are found when the design method is implemented in routine design practice. The developer of the method is not involved in implementation and evaluation. These studies should determine whether the design method can improve outcomes under normal conditions.

Example: Industrial researchers (not the table design tool developer) test the table design tool using the engineers at their organization (which designs tables) and collect data to determine if the engineers who used the table design tool generated better solutions than those who did not.

Research Type #6: Scale-Up Research

Scale-up research studies test a design method in many different conditions, including multiple populations and those who are not the target users. The developer of the method is not involved in implementation and evaluation. These studies should determine whether the design method can improve outcomes under a wide range of conditions.

Example: Design researchers test the table design tool using high school students, college students, and practicing engineers in many countries to determine if designers who used the table design tool generated better solutions than those who did not.

4. A Framework

These research types, although listed in a sequence, actually form a cycle of research that iterates through three "phases": description, explanation, and testing (Meredith, 2001). In this cycle, researchers observe and describe a phenomenon, develop theories to explain the phenomenon and its interactions and effects, and test that theory against the phenomenon, and then, based on the results, refine their descriptions, revise their theories, and conduct more testing. Over time, the description of the phenomenon is improved (e.g., made more precise or more general), better explanations (theories) are found, and additional testing further demonstrates their correctness (or indicates their limitations). Paredis (2015) presented a similar research cycle that included developing theoretical explanatory models, creating better methods and tools, and empirical characterization and falsification.

Of the six research types presented here, Research Type #1: Foundational Research and Research Type #2: Early-Stage or Exploratory Research are most concerned with description and explanation. The other four research types (#3, #4, #5, and #6) are most concerned with testing. Research Type #3: Design and Development Research creates something that needs to be tested and may include some limited development and pilot tests. Research Type #4: Efficacy Research tests a method under optimal conditions, Research Type #5: Effectiveness Research tests a design method under typical conditions, and Research Type #6: Scale-up Research tests a design method in many different conditions.

A design research effort can expect to progress through these research types while iterating through the research cycle and, as needed, going "back" to study interesting, unexpected phenomena that are revealed in testing at any point. For instance, an effectiveness test may show that a design method works poorly when used by some types of engineers in certain situations,

which motivates additional research to study and describe this behavior, explain why the method works poorly, and enhance the method in an appropriate way.

5. Discussion

The proposed framework lists six research types. The research types follow a logical sequence in which researchers develop basic knowledge, create design methods, and test design methods. Although the framework numbers the research types following this natural progression, it does not insist that researchers do or should work by rigidly following this sequence. As mentioned in the previous section, these types are part of a dynamic research cycle, and researchers do and should perform the type of study that is most appropriate based on their knowledge, the evidence generated, and their individual interests.

The proposed framework, by adopting the research types in the Common Guidelines, does not have a single research type that is exclusively focused on observing design work and describing what designers create and how they create it. Such descriptions can add new knowledge, however, and can be considered part of Research Type #1: Foundational Research.

The proposed framework does not categorize research by the application domain, the complexity of the product or system that is being designed, the phase of the system development process that is being studied, the type of design activity, the amount or type of uncertainty that exists, or the number of persons involved in the activity. This deficiency does, however, make this framework more general because the framework can be applied to any design activity for any product or system.

The proposed framework can show how different research studies are related to each other because they are the same research type or they fit into the progress of a design theory or the development of a design method. Thus, the proposed framework, while not a theory of design, can help researchers respond to the challenges of coordinating the different types of research (analyzing design practices, generating and testing hypotheses, and measuring the effectiveness of design methods) needed to create useful design theories, understand the "ecology of theories and methods," and build a unified body of knowledge (Le Masson et al., 2013).

The proposed framework itself can be seen as a description of design research that needs to be explained more fully and tested thoroughly. Although it is based on the fundamental ideas of the scientific method, perhaps a more complete explanation can be found in the existing body of knowledge about the nature of science. More thorough testing could proceed through a comprehensive literature review that classifies existing work, but this would require enormous effort. A more organic approach could be to organize a peer-reviewed process in which design researchers classify their own work using this framework and collectively show how well (or how poorly) this framework matches what design researchers do. Such testing would lead to improvements in the framework or a completely new way to understand the field of design theory and methodology.

6. Summary and Conclusions

This paper presented a framework for design research as a means to increasing our understanding of the field of design theory and methodology. It presents and defines six research types and provides brief examples to illustrate them. The Common Guidelines discuss research and development activities that sought "to increase learning." Similarly, the proposed framework is meant to describe research and development activities that seek to improve design.

Future work is needed to analyze, test, and refine this framework so that it becomes truly useful to the design research community.

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