CONCATENATING POSTGRADUATE THESIS DESIGN WITH SOCIAL SCIENCE RESEARCH

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ARTICLE INFO	ABSTRACT
	Main Objective: The main objective of this study is to empower designers to collaborate with researchers in other disciplines — especially in the social sciences — by articulating a design inquiry model that can be implemented in a master's program in design. Background problems: Modern research problems are complex and design needs to be better integrated with the social sciences and play an equal role in addressing them. A final master's degree in design prepares students for this integration, but design activity should be evidence-based rather than viewed retrospectively as a form of research without change. We need to adapt to ultimately contribute to research. Novelty: There are main criteria for design-based inventions in this study, including value, relevance, novelty, focus, transferability, and practicality. When these criteria are met, investigations can operate within the social sciences, or they can be leveraged and serve as the discovery phase in evidence-based inquiry. Research Method: This study presents design-based discovery, a design inquiry model that places design in the theory development cycle as theory building, not theory testing. This research, therefore, uses a design inquiry model approach, (invention-based design) in other disciplines by articulating a design inquiry model that can be implemented in a master's program in design to be complementary and compatible with social science research. Finding/Result: A proposed design inquiry model with design exploration serving as the research discovery phase guiding the design activity to make specific contributions to areas of social science that are outside of design. It involves a careful process with six investigative components, all ultimately connecting the knowledge base beyond design to design exploration. Conclusion: This study proposes six main criteria for design-based inventions: value, relevance, novelty, focus, transferability, and practicality. In the model proposed in this study, the six investigative components are described and supported with examples. Notably, the investigative

component includes a standardized format for research questions, as well as the derivation of design principles from processes that involve exploration rather than one that generates solutions. This model can easily be adopted in other master programs with the necessary resources. In addition, this model, if placed in design activities in evidence-based research practices, can become wider. There is no claim that a designer's self-reflection equates to a strictly social science method so design researchers must continue to study design and build on their knowledge of the discipline.

Keywords: *Design Thesis, Social Science, Postgraduate Thesis Design*

1.   INTRODUCTION

Contemporary design research problems are increasingly complex, Davis underlines the considerable limitations of a master's degree in design to address these issues (Davis, 2020:206). Design research must continue to advance in both academia and industry, and with the broad professional skills burdening undergraduate design education a terminal master's degree must play a central role and "enrich the capabilities offered by the profession" (Davis, 2020:211). Davis lists experiences that are rarely obtained by graduates of a master of the design program, including "Asking questions that really can be researched", "Being aware of several research paradigms and appropriate standards", "Constructing methodical rigorous investigations", and "Writing papers more the length of several pages." (Davis, 2020:206)

In the absence of this experience and the competencies developed by graduate designers, such graduates may be prepared to tackle the "problems of well-structured appearance and function" of the past, but not the interdisciplinary and multidisciplinary work required today (Davis, 2020:206). While nominal research engagement in the industry can often be characterized as opinionated, "practitioner personal experience," or privileged case studies (Fisher et al., 2018:61-62), graduate education is an opportunity to indirectly enhance design research (Littlejohn, 2017:33-51), making it more generalizable and thus more impactful. Master program graduates can bring research competencies to industry, or remain in academics as professors to develop these competencies in their students, who continue the cycle. Those who remain in academia will also directly contribute to the production of their research.

To enable this benefit to emerging design disciplines, this research focuses on the basic characteristics of contemporary research problems that Davis emphasizes: for such many complex problems, no single discipline can address them (Davis, 2020). This research aims to empower designers to collaborate with researchers in other disciplines — especially in the social sciences — by articulating a design inquiry model that can be implemented in a master's program in design. This model of design inquiry, or design-based discovery, is complementary to and compatible with many research practices in the social sciences.

To facilitate the adoption of this model in other master programs, it will be explained: the context of the current implementation; investigative components that must be produced by students; component assessment criteria; selection of sample components that make the description more real; and student competencies to be developed, including required courses and institutional infrastructure. The relationship between design and research programs as they are known elsewhere in the university has important implications. For example, the long-term health and feasibility of a design, in a context that assesses and evaluates research results, depends on design representation — in academia, these representatives are design faculty. The social sciences are often distinguished from the humanities according to which disciplines one or the other belongs to in their scientific field, which is not very helpful (at least for designers), as these disciplines are placed inconsistently across lists. In contrast, the definition of social science is simple, in line with usage, and very vague: "the scientific study of human society and social relations" (emphasis added). [As of July 2021, definitions showing in Google searches and Apple Dictionaries are taken from the Oxford Language dictionary, which is different from the Oxford English

Dictionary.] "Scientific" emphasis on supporting the social sciences—or the blurred-border subdivision of social sciences focused here—by positive knowledge claims. Research design theorist John Creswell describes postpositivism as, "a deterministic philosophy in which causes may determine effects or outcomes," and relates it to the scientific method [Creswell, Research Design, pg. 7]. The social sciences are consistent with an objective and imperfect quantitative study of the phenomena associated with postpositivism, as well as a more pragmatic use of mixed methods that also incorporate qualitative data collection for triangulation with quantitative data. When using the term social science, refers to a subset of the social sciences, while others consider it to be the social sciences as a whole.

Davis has suggested that design faculty are in danger if they simply position themselves as special within the university, as opposed to demonstrating how they are important (Davis, 2016:123-131). Especially within research universities, design faculty will have to isolate themselves or find ways to interact meaningfully with experts in other fields. disciplines. Many funding agencies expect evidence-based investigations to be of the highest standard, and will not make exceptions for design idiosyncrasies. While design faculty often define design research in ways that are excluded from scientific standards circles at universities, Davis cautions that:

> "…alternative rules of the game for design schools undermine developing a mature research culture and maintaining discipline around many of the university's most valued activities. Further, they limit the ability of design faculty and graduate students to work as equal partners in funded research that has an impact outside the university." (Davis, 2020:209)

Design-based discovery positions design exploration as the discovery phase of research in the social sciences, making design essential. It does so without claiming that normal design activity results in the generation of new knowledge, which is becoming the standard of evidence-based inquiry. As such, it does not seek to replace research in the social sciences but aims to contribute to it.

2.   LITERATURE REVIEWS

Master's Degree in Design

Traditional design education emphasizes doing design rather than studying it, without teaching students how to base design decisions on empirical evidence or to interpret research conducted in non-design disciplines (Littlejohn, 2017:36). There is confusion about the place of research in curriculum design (Davis, 2008:71); (Davis, 2012: 111) and what is meant by research design research by design (Corazzo et al., 2020: 7). New doctoral programs (both Ph.D. and D.Dec.) and masters programs proliferated against this backdrop of confusion, broadening postgraduate offerings at a time when designers still struggled to complete design research with "typical" academic research (Corazzo et al., 2020:20). During this period of expansion, design programs and the discipline as a whole had to negotiate definitions of research in design (Davis, 2020:211). Undergraduate studies in design are vocational, and postgraduate studies, often continue into vocational education with little difference from undergraduate studies. Masters programs often follow a fine arts curricular model, sometimes with minimal coursework in favor of independent study that is only occasionally subject to faculty criticism, which tends toward an emphasis on developing artifacts to the exclusion of effective engagement in research methods (Davis, 2020:208).

Masters study should be limited in part according to what program faculty perceive to be the nature of research—whether they believe their program allows such research mastery or is a preparation for it. Doctoral studies represent the highest level of research practice, and thus when a doctoral program is adjacent to a master's program, or when the faculty has a concrete idea of what doctoral study represents, it can serve as a guideline in which master's studies are oriented and understood. There are practice-based and evidence-based doctoral degrees. The practice-

based doctorate has made it central to its model and is familiar territory for designers, where faculty do not need to adapt their design practice to the standards of other research activities (Davis, 2020:209). Evidence-based dissertations investigate some phenomena as experienced by others. It does not center on a single artifact or system of student-made artifacts, nor does it ask researchers to engage in self-observation. Evidence-based doctoral programs train students to engage in rigorous methodology, use specialized sampling methods, and analyze statistics to compare and assess data, all of which are beyond the scope of what can be covered in two years' worth of study at the master's level. Nevertheless, master's students can develop a "research-sensitive disposition," and apply knowledge from other disciplines in their work (Davis, 2020:209). A master's degree can undertake a more open-ended exploration of design in a studio-based course while developing behavioral academic research in other courses that involve little or no design activity. It can thus serve as a bridge between familiar design practices and foreign research practices.

Research Design and Practice

Scholarships in research in design — or research conducted by designers — are largely concerned with learning more about the design activity itself; namely, how the designer does the design (Bayazit, 2004); (Buchanan, 2009): (Cross, 2007); (Dorst et al., 1995). An increasing understanding of the nature of design activities (Ball et al., 1999) has led, among others, to practice-based or practice-led design research (Archer, 1995:6-13); (Candy et al., 2018:63); (Giaccardi, 2019); (Green et al., 2005); (Rust et al., 2007), which is the foundation of a practice-based doctoral degree. Practice-based design research generally uses self-design, where the design researcher effectively intends to learn more about the nature of the design by designing it himself (Pedgley, 2007:463-483). This blurs the distinction between "practice work" and "research work" in design which Cross argues should be maintained (cross, 1999:9), and relies on the researcher's own opinion and individual experience (Fisher et al., 2018:63), which subject to deep bias. In general, research is inconsistently defined in the design, and design research can be "prone to claims of superficiality" (Fisher et al., 2018:61-62). The definition of design research, especially the definition often cited by Frayling (Frayling, 1993:1-5) and Archer (Archer, 1995) is ambiguous enough to be interpreted inconsistently and applied to adjust preconceptions and needs (Fisher, 2018). Frayling's articulation of design research (Frayling, 1993) is a means of placing art and design within a broader scope. academic research practice, but he outlines the types of design research by retroactively labeling what designers already "actually do" in practice as research, rather than detailing what might be done differently to integrate design with relevant and established research practice.

In contrast to practice-based design research, inquiry in the social sciences is primarily aimed at generating new and generalizable knowledge. In this context anecdote, where research is design based, is particularly problematic. Research practice in most social sciences seeks to generalize knowledge, reduce methodological bias, and minimize the level of anecdotal results. Philip Cash provides a model of theory development (Cash, 2018:84-119) — necessary for the production of generalizable knowledge — that can effectively constrain design activity. Cash's theory development cycle includes three phases of theory building and two phases of theory testing (Figure 1). Theory building begins with discovery and description, which involves "identifying areas of interest and important issues" by "asking questions that establish the general characteristics of what is going on in a situation." (Cash, 2018: 88). This continues with the definition of variables and domain boundaries, which involves "identifying variables and mapping out interconnections and boundaries" by "asking questions to identify key variables and identifying salient themes, patterns, and categories." (Cash, 2018:89). Variables of interest are often at the center of investigations in the social sciences, especially about generalizations. Measurement by a variable of interest is a matter of theory testing mode, which in one cycle is then fed back to theory building mode, gradually increasing knowledge. This is new knowledge

of evidence-based inquiry — "knowing" from the knowledge community (Dixon, 2019:7) —not personal knowledge ("I know").
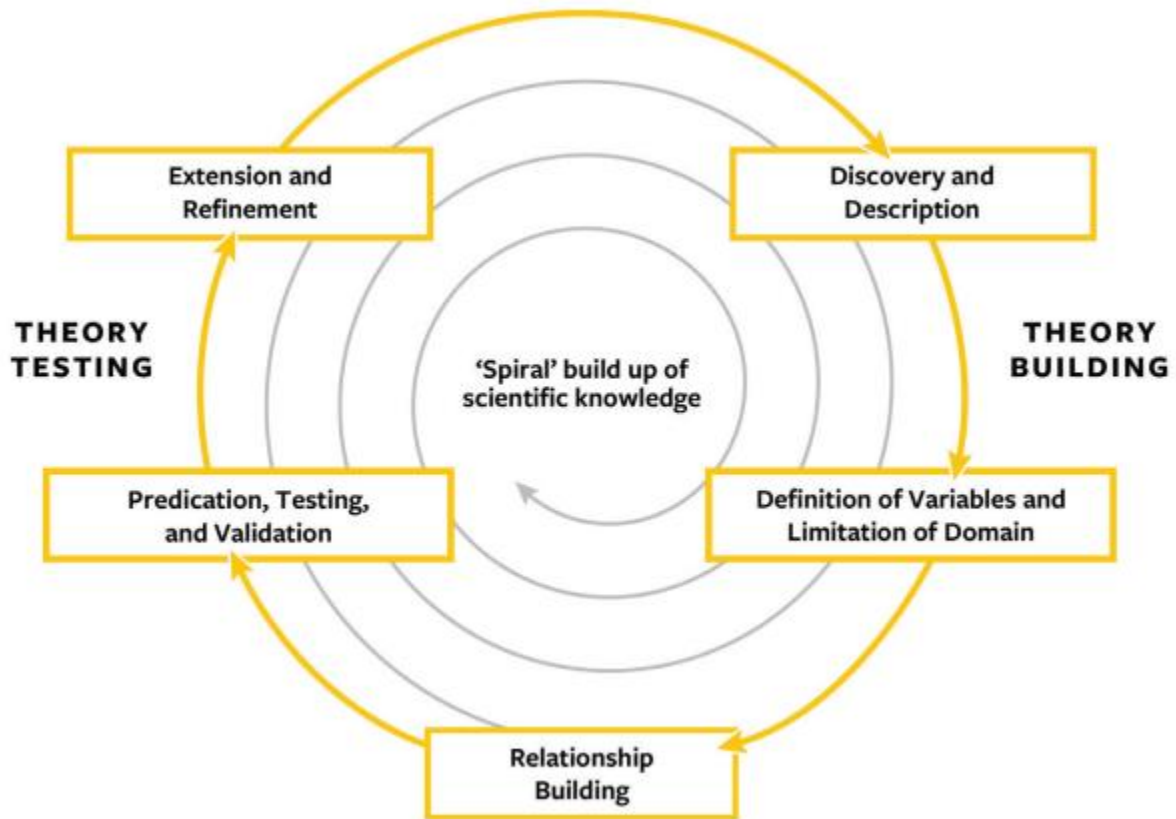

Figure 1: Theory-building and theory-testing cycle, redrawn from Cash (2018, p. 88)

There is no need for designers to break into established disciplines and create new modes of testing and validation. Instead, with Cash's theory development cycle, the design activity is essentially a matter of "discovery and description" — specifically as a form of lateral thinking (that is, a nonlinear, creative way of tackling problems indirectly). In addition, if designers have at least some familiarity with the knowledge base rooted in the social sciences, they can think in terms of the "variable definitions and domain constraints" necessary to move findings further through theory development.

3.   METHODOLOGY

Design-Based Discovery: The Academic Model of Design Inquiry

A model of design inquiry that rigorously guides design exploration as the discovery phase of research in the social sciences. Discovery refers to discovering something unexpected, which regularly occurs in design explorations. Design-based discovery differs from practice-based research through design model (Pedgley, 2007) in two fundamental ways: (1) it does not consider normal best design practice to include or preclude theory testing, instead limiting design activity about, and within, full theory development cycle; and (2) this is not related to the search for solutions but is intended to produce variability which can then lead to the next phases of the theory development cycle. Variability is inherent in any design exploration.

There is humility to this design activity – it is not asked to be the equivalent of a full theory development cycle. In contrast, design exploration represents the discovery phase (Kaplan, 1998). Research through design is concerned with coming up with the "right thing," (Zimmerman et al.,

2007:499) that is solution-based, nevertheless linked to anecdotes. In contrast, models that seek multiple things may be more appropriate to incorporate design as an important part of ongoing evidence-based investigations. In harmony with evidence-based inquiry, design-based discovery is based on the postpositivist paradigm, which holds that "there are laws or theories that govern the world, and these need to be tested or verified so that we can make sense of the world" [Creswell, Research Design, p. 7]. However, such testing and verification is after the design-based discovery

Design-based discovery has been implemented in a master's program that includes extensive studio-based instruction, where there is not enough time for students to acquire expertise in well-established empirical methodologies in the social sciences. But designers can collaborate with experts in other disciplines if they have a basic understanding of the language of social sciences and the means to improve their design skills in the theory development cycle. Unlike expertise, this level of familiarity can be achieved within the context of a master's program in design. This study proposes six main criteria for design-based inventions: value, relevance, novelty, focus, transferability, and practicality. When these criteria are met, investigations can operate within the social sciences, or they can be leveraged and serve as the discovery phase in evidence-based inquiry. Each criterion is directly related to one component of the investigation: problem statement, justification, conceptual framework, research question, model of inquiry, and design principles. Each component demands something special from the designer, which must be supported in the previous course. The investigative component defines and, in principle terms, responds to visual and interactive studies (i.e., design exploration). The criteria and components are summarized in Table 1, while the component relationships are depicted in Figure 2.

Table 1. Design-based discovery criteria about investigation components.

| Criterion	Demand on Designer	Investigation Component
Value	Logical Argumentation	Problem Statement
Relevance	Opportunism	Justification
Novelty	Analysis	Conceptual Framework
Focus	Clarity of purpose	Research Questions
Transferability	Disciplined variability	Investigation Model
Practicability	Pattern finding	Principles (in Discussion, as derived from design studies)
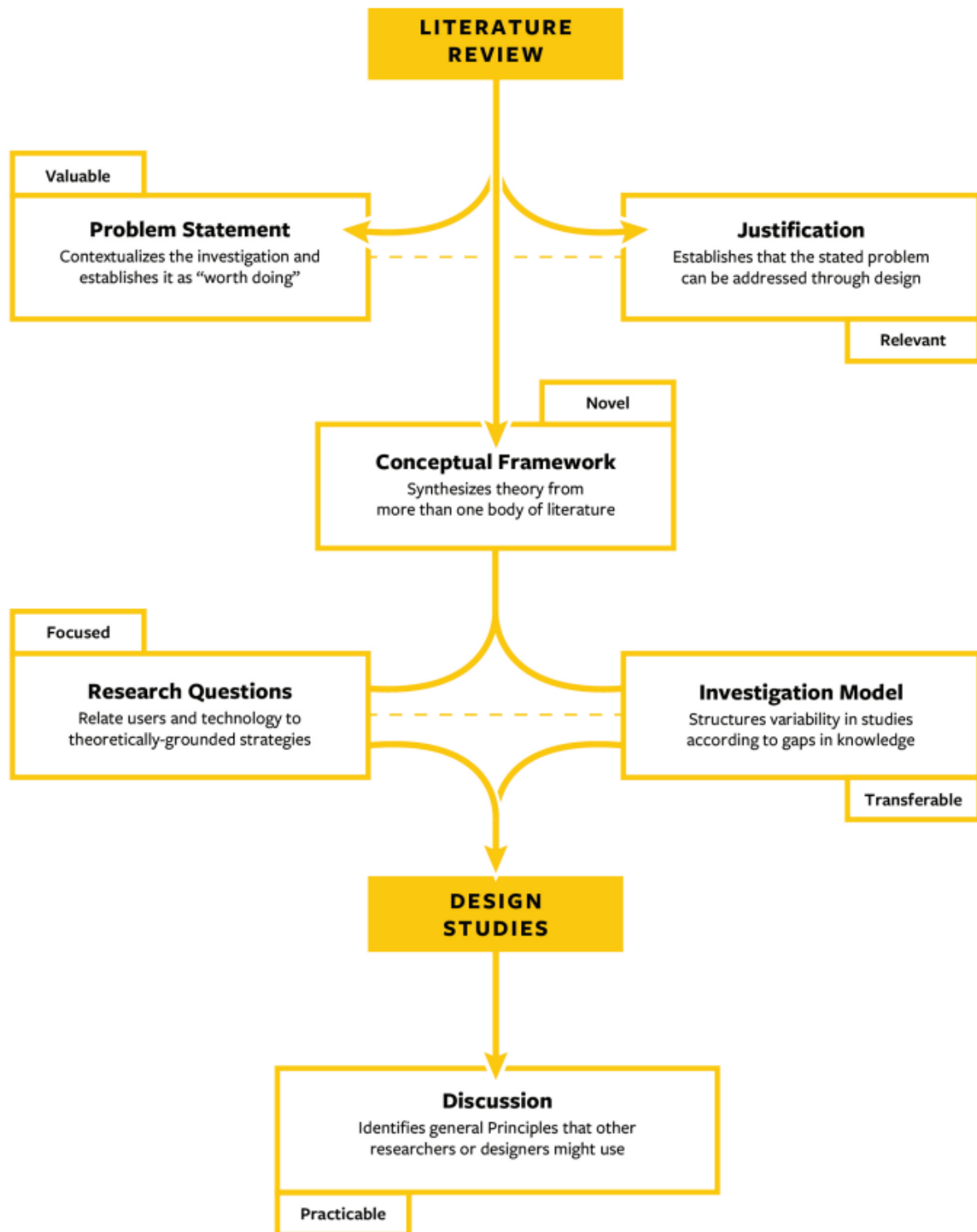
Figure 2: Design-based discovery, corresponding primarily to Cash's discovery and description phases, but extending to variable definitions and domain phase constraints (see Figure 1).

In their description of the Ph.D. practice-based, Pedgley and Wormald drew on the skill of the designer as justification for treating the work as research (Pedgley, 2007:77). Rather, design-based discovery as a model in itself ensures that the work is relevant. to and implicitly integrated

into inquiry in the social sciences. As with other efforts by full cohorts of students, the quality of the response will fluctuate, while the model lasts.

Model Development

The design-based invention context outlined here is a two-year terminal professional master's degree that roughly covers communication and interaction design. Like the bachelor's degree, the master's degree features studio-based instruction but also includes a curated program of critical reading with ongoing, substantive writing demands. Doctoral programs continue the latter but add cognate courses—methods courses taken in other disciplines at the university—and statistics or philosophy. Both levels of graduate study include a review of the literature, but at the masters level students make use of theory, whereas at the doctoral level and with increasing expertise, students go beyond simply leveraging theory to interrogate and develop it (or "theory testing," in Cash's terminology) (Cash, 2018)). Masters-level work in core studios is more speculative and critical. Doctoral work produces new knowledge in the strictest sense — not self-knowledge or exploratory anecdotal reports, but the knowledge that can be generalized (Lee et al., 2003:221-243).

In the Master of Graphic Design program, students produce a sis document (the university designates this kind of thesis as a "final project"), which is physically archived and accessible in the university's branch library. Available thesis documents were collected for the existence of the six components of the current model investigation (listed in Table 1), to ascertain the extent to which the model emerges rather than is discovered. The earliest archived thesis document is from 1993, and a total of 158 documents are available for analysis. After breaking down into groups of size 12–18, starting with 2020 and working backward, trends over 11 consecutive periods can be tracked. Although many of the individual investigative components appear quite frequently throughout the history of thesis documents (Figure 3), very few documents fully comply with current standards with all six components present (Figure 4). This suggests that all components existed at least occasionally in earlier years when the structure of the thesis documents varied widely and was largely determined individually by the thesis student and the chair of the faculty committee (who oversaw the development of the thesis documents). This also seems to confirm the general history of the Master of Graphic Design thesis as delivered personally by Meredith Davis, who was instrumental in the evolution of the thesis in the Master of Graphic Design program during most of its history, and who founded the thesis preparation course more than twenty years ago. Thesis preparation courses create space for standardization. Unsurprisingly, theses from the 1990s that preceded this course, launched in 1998, were wildly inconsistent in how they envisioned research.
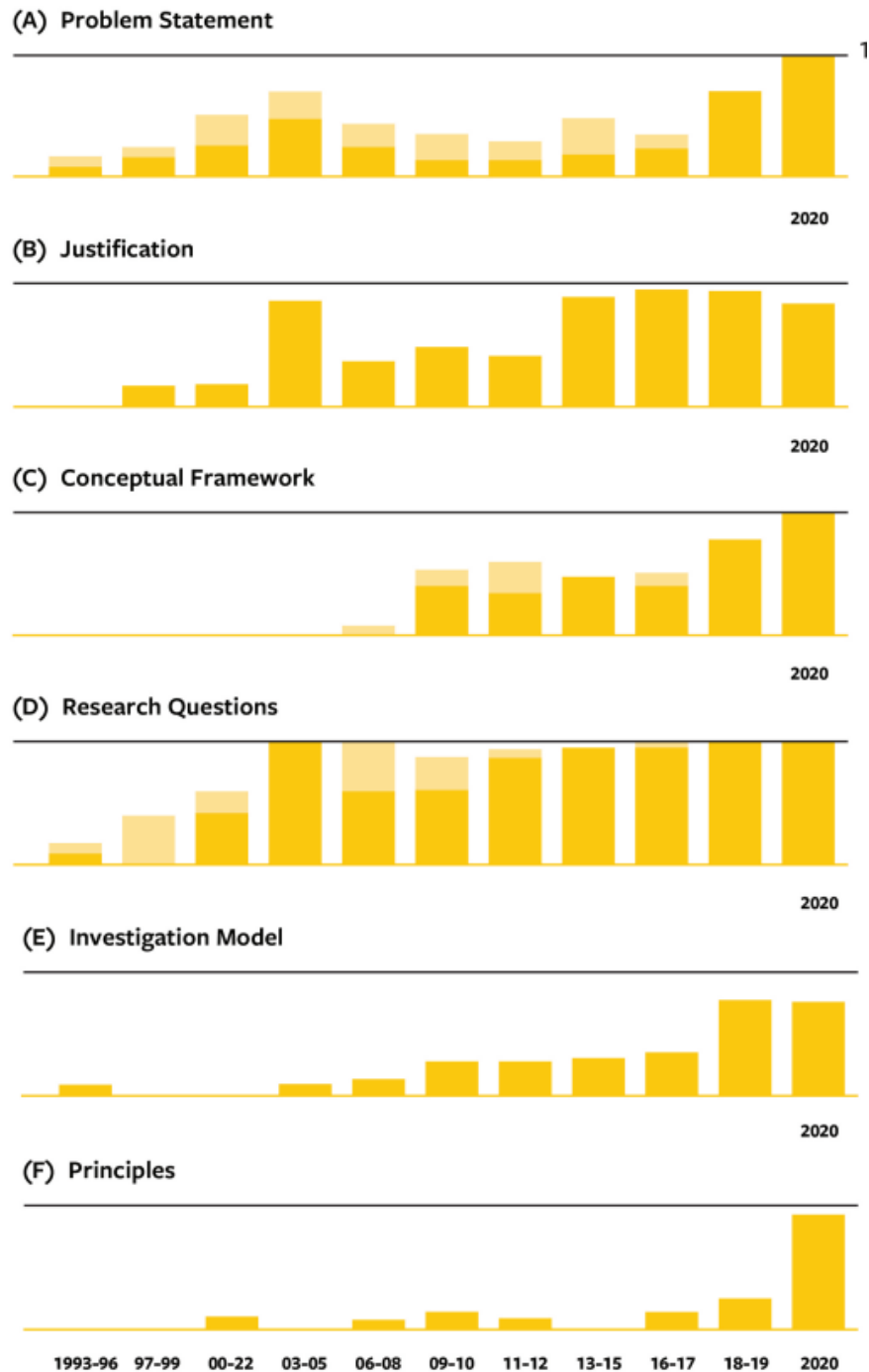
Figure 3: Compliance of components with current standards in the previous thesis document as the frequency of component presence. (A) Statement of problem: light yellow indicates the title "statement of problem" incorrectly used for a research question, with no additional content; solid yellow indicates sections with different content. (B) Justification. (C) Conceptual framework: light yellow indicates the presence of a diagram reminiscent of a conceptual framework but with minimal theoretical synthesis. (d) Research questions: light yellow indicates a single question or no hierarchy for any question; solid yellow

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indicates a main question with appropriate sub-questions. (E) The investigative model. (f) Design principles. The year in brackets in each sample is provided at the bottom.
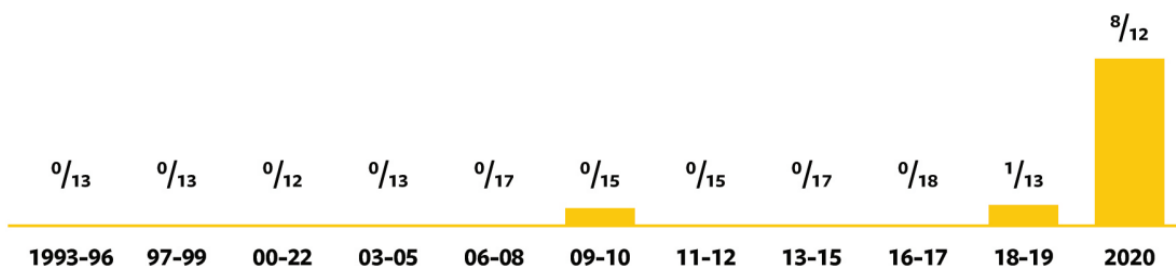

Figure 4: Full compliance with current standards in the previous thesis document: an example covering all six components. This survey was carried out before the submission of the 2021 thesis documents. Given the strengthened requirements, it is likely that 100% of the documents are in full compliance

Although all of the investigative components of design-based inventions emerged during Davis' tenure, the standardization of design-based inventions as a model occurred only recently, after his direct involvement in the master's program ended. The codification of design-based findings involves analyzing the most recent thesis approaches that appear to be most aligned with the research of other disciplines at the university and coordinating these approaches. Of the investigative components that make up the model, the least common, and thus the most emerging, is the articulation of design principles that follow the study. Principles derived from studies are meant to go beyond investigation as anecdotes — so this component is a defining characteristic of design-based findings. Each of the design-based discovery criteria is discussed below, together with the appropriate investigative components

Mark

The grades criterion requires that the investigation is worth doing, and has an impact far beyond the student's personal growth, or what might just be the start of an interesting conversation. This is accomplished through the problem statement, the initial part of the thesis document. Assigning values requires logical arguments. To demonstrate that problem space is worth exploring, the designer must provide evidence that a problem exists about a particular product or service user group; it cannot be a matter of opinion. The following is a flow of reasoning for a project by Jessye Holmgren-Sidell that prototypes a physical device, which facilitates the reading of parent-child picture books for severely blind children (Holmgren, 2019).

> "Picture books can facilitate preschoolers' literacy comprehension and ability to retain information […] (Fang, 1990:130-142); (Strouse et al., 2018:1-4). Through interactive reading with their parents, children begin to internalize the illustrations they see in stories and apply them to real-life experiences […] (Strouse et al., 2018). As a vehicle for conceptualization and visual communication […] (Shulevitz, 1985), picture books offer a range of potential benefits for young readers, but exclude visually impaired readers." (Holmgren, 2019:14)

This sets the value of the further investigation. Evidence for the importance of parent-child reading with picture books comes from literature rather than designer beliefs: "Bishop […] also recommends early intervention for children who are visually impaired, noting that interactive experiences provided by parents and teachers (eg, tactile exploration) can help concepts and their cognitive development." (Holmgren, 2019); (Bishhop, 1996). Hernon and Schwartz provide attributes of the problem statement, as well as a short exercise is taken from David Clark to conceptualize the problem statement before writing it in full (Hernon et al., 2007:307-309). Three

sentences are composed: an introduction, a statement of originality that also identifies what the investigation will "do", and a justification (Hernon et al., 2007:308). These statements can then be expanded into part documents that are supported by the literature.

Relevance

The relevance criterion requires that the investigation be placed within the larger research context and that the problem it states can be addressed, at least in part, through design. This is achieved through justification. Relevance requires opportunism. The designer must find gaps in the literature or opportunities to apply existing theories to new situations. For example, picture book reading devices fill a need that was not well understood: "There are currently no extensive systems that blind children and their parents can apply to exist picture books to make them an accessible and interactive reading experience. " (Holmgren, 2019:16). Justification requires students to articulate why the design has "something to say" about the problem. The first part of the document that students complete in a thesis preparation course is an analysis of design precedents, which helps them formulate a justification.
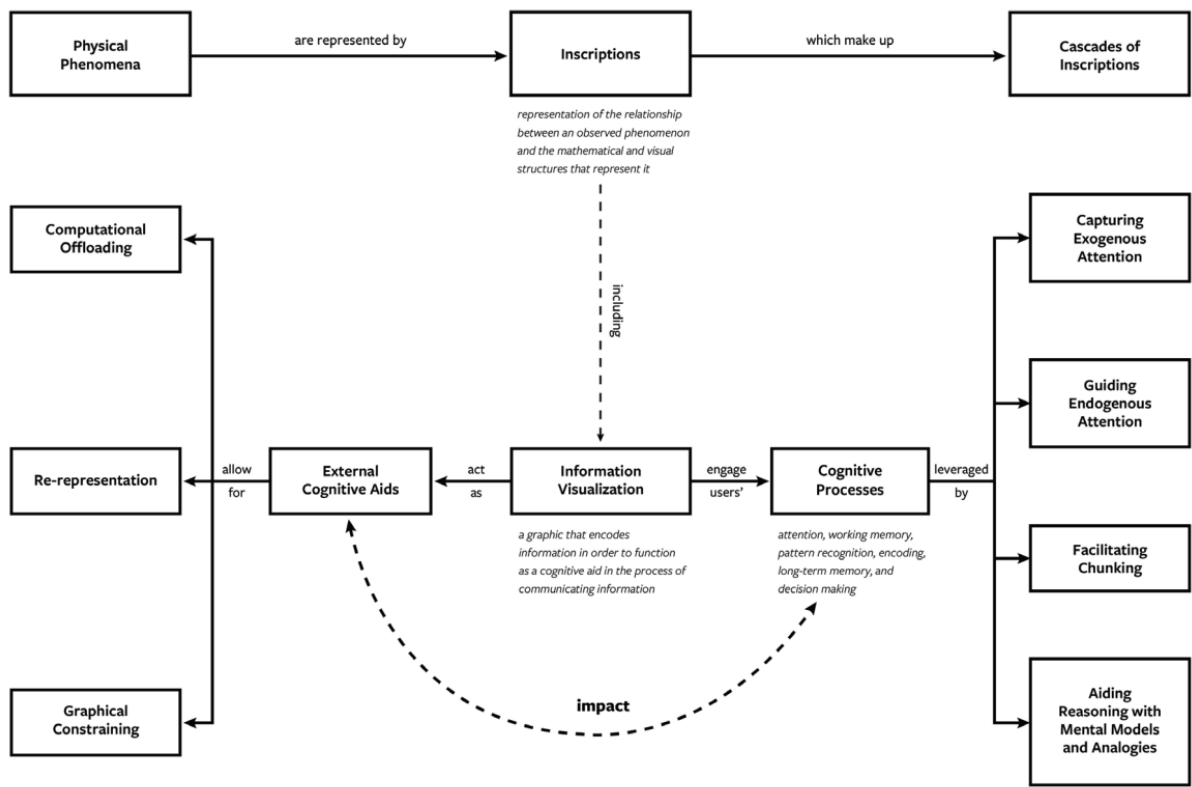

Figure 5: Conceptual framework for the perception of uncertainty in data visualization. Redrawn from Hill (2018, p. 26)

Novelty

The recency criterion requires that the investigation synthesize theory from more than one field, ensuring that the study will not be redundant with previous work. This is achieved through a visualized conceptual framework, which (if new) is a contribution even before the study is conducted. Novelty requires analysis. Figure 5 reproduces the conceptual framework of a project on the perception of uncertainty in data visualization by Mac Hill (Hill, 2018:26). It synthesizes theory from three sources (Patterson et al., 2014:42-58); (Scaife et al., 1996); (Ball, 1997), and then linked to other sources of uncertainty (Skells et al., 2008). The conceptual framework describes the designer's conceptualization of thinking as shaped by a review of the literature. This

gives structure to the relevant literature about the problem. The extent to which the investigation is valuable, relevant, and novel are defined in the project definition and precedes the design activity. The extent to which inquiry is focused, transferable, and practicable—the remaining criterion—is determined by the design's unique contribution as a mode of exploration. This exploration is formalized in a series of coordinated visual and interactive studies

Focus

Focus criteria require that studies are based on, and can be interpreted about, stated gaps in knowledge. This is achieved through structured research questions, which target those gaps and should precede the study. Focus in the study requires clarity of initial goals. Research questions guide the researcher's design activity, suggesting "methodological and philosophical approaches" while identifying the people, concepts, and circumstances under study (Davis, 2015:135). Research questions are critical to guiding research practice in the social sciences. Davis provides criteria for a "good" research question in the context of design, including hierarchical implications in the aspects of the problem, the definition of terms, reliance on working theory, setting a realistic scope, and anticipating how and by whom any findings will be used (Davis, 2015: 135-139). A 2014 analysis of academic research in the UK found graphic design research "weak in general," (REF, 2015:85), and subsequent analysis by Corazzo and colleagues emphasizes the absence of research questions in graphic design. research statement (Corazzo, 2014:23). Their recommendations for academics include "a clearer focus on identifying and answering specific research questions (Corazzo, 2014:26)." Research questions are thus not provided in the design, and students need support in constructing them. Design-based findings are increasingly formulated in the way research questions are structured: one main research question followed by three or four "sub-questions". In the social sciences, evidence can be constructed to "answer" such questions. As a discovery phase only—not part of theory testing—design-based discovery does not consider responses to questions to be answered, but more speculatively as explorations, even if such responses are rigorous. The main questions are never answered right away, they are broad in scope. Instead, it declares an underlying intent and leads to subquestions, which are, in turn, directly actionable, and have appropriate scope for design exploration. In design-based discovery, the main question must address all, and subquestions of some of, the five elements:

1. People: who benefits from the investigation and what is special about them.
2. Technology: what is being prototyped, or what are people going to use?
3. Setting: how people will interact with the technology, or under what conditions this interaction will occur.
4. Outcome: what operating the technology will achieve for people.
5. Means: how the operation of technology will achieve results.

The relationship of results to means, and of the elements to the problem itself, is logical and supported by well-established knowledge from the literature. For example, the outcome means of threading subquestions to the main question in a picture book toolkit for the visually impaired include token gestures by hand to model visualized actions in picture books, which helps children construct schematics of events and scenes, which in turn facilitates literacy understanding (problem statements assign the value of understanding literacy for child development). In this thread, "the" denotes a statement that is supported by the literature. The designer's job is to demonstrate the various actions that can be modeled with tokens. Anderson (2020) is interested in digital mediation cognitive behavioral therapy (Rozenral et al., 2018:1-15), which usually takes the form of practicing in a therapist's office, helping patients identify and challenge negative thoughts, and then consider alternative thoughts. Anderson's main questions and sub-questions together demonstrate the specificity needed to guide design exploration:

1. How can digital therapy tools challenge negative automatic thoughts for undergraduate students experiencing anxiety to achieve more balanced thinking in daily planning and goal setting?
2. How do multimodal image builders utilize unique personal visualizations and metaphors to help students new to metacognition represent their thoughts through imagery?
3. How can the multimodal image builder suggest alternative views or perspectives help students identify and reframe negative automatic thinking?
4. How can interactive visual cues disrupt negative thinking patterns to help students practice using alternative thoughts and images to manage their goals in moments of high and low stress? (Anderson, 2020:18)

Because developing research questions is both important and difficult for students, short exercises requiring statements of each element of the question are also assigned. These exercises are not framed as related to the research question, which helps students to focus on possibilities and relationships without being overwhelmed by the structure of the research question. When students are ultimately asked to create a formal research question, they already have the option of compiling the necessary elements that they can incorporate.

Transferability

The transferability criterion requires that design explorations take the form of successively scheduled studies. Studies should be coordinated to prove instructive for other situations in the aggregate and beyond the idiosyncrasies of each study. This is achieved through an investigative model, which defines and guides the study. Transferability requires disciplined variability. Even well-formulated research questions can fail to guide design exploration. To provide actionable directions for studies, the investigative model organizes subquestions into small effective project summaries. Each subquestion represents a different request for design exploration. There is always a theoretically justified guide for the designer to vary the studies. For example, in Hill's uncertainty in data visualization project (Hill, 2018), four of the six leverage points that influence the cognitive power of information visualization (Patterson, 2014) (e.g., capturing exogenous attention) map to four subquestions and form one axis of the investigative model, which manifests as a matrix (Hill, 2018:27). The secondary axis, which is represented in the additional subquestion, connects those leverage points to the four types of uncertainty in the data (Skeels, 2008) (eg, uncertainty disagreement). Each cell in the resulting investigative model represents a unique study. Meaningful comparisons across studies placed in rows or columns go beyond what are individual anecdotal studies to disciplinary variability. As noted, the systematic relations of theoretical constructs speak the language of variables in the social sciences.

Table 2. Investigation model for the perception of uncertainty in the data visualization project, prompting 16 studies, from Hill (2018:46) (Ultimately, select studies among the possible 16 were not conducted, as they were deemed redundant)

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	Inference uncertainty	Disagreement uncertainty	Completeness uncertainty	Precision uncertainty
Capture exogenous attention	Study 1a	1b	1c	1d
Capture endogenous attention	2a	2b	2c	2d
Facilitate chunking	3a	3b	3c	3d
Aid reasoning with mental models and analogies	4a	4b	4c	4d

It is also possible to use the investigative model in projects that are more concerned with a single prototype, such as in a blind picture book toolkit project. The difference is that in such investigations, each subquestion derives its suggested variability from several different theoretical constructs, and the variability occurs in the exploration of one feature at a time — the designer explores the various forms and functions of a particular feature. In both cases, the study variety is deemed more valuable and transferable than whatever solution the designer subjectively deems best. The investigative model does not need to be in the form of a matrix. Anderson provides an example that explains the difference between a conceptual framework and an investigative model while presenting the latter in diagrammatic form (Anderson, 2020:). The conceptual framework (Figure 6) regulates the concepts underlying the investigation, (Akimoto, 2019:342); (Beck, 1976); Epstein, 2003); (Herman, 2013); (Josefowitz, 2017); (Yang, 2012), but it is an investigative model (Figure 7) that directly addresses what will be executed through design exploration. The model investigation describes the cycles of cognitive behavioral therapy and maps the studies to the stages of the cycles that they address as features in a system. It is also clear, as labeled, that the subquestions are relevant to the study.
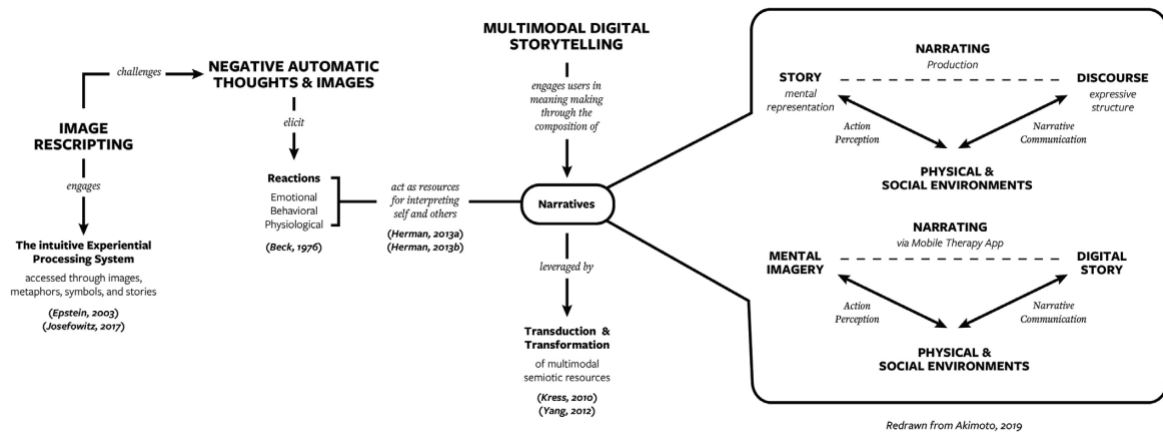

Figure 6: Anderson's (2020, pgs. 16–17) conceptual framework synthesizing several sources

IMPLICATION (RESULT)

Practicality

The practicality criterion requires that any tentative results can be used by other researchers. This was achieved through sub-sequential studies and discussions. Practicality requires finding patterns that result in the articulation of design principles. It is the designer's job to derive principles from visual and interactive studies. It is these principles that make inquiry practicable,

with study ultimately serving only as an example of those principles in action. The derivation of principles requires the discovery of patterns — a well-known skill of designers (Cross, 1982:244) — which must be proven to others through discussion chapters in written documents. However, the variability of the disciplinary studies must be documented, so that others can derive principles that have been neglected by the designer. Such principles must be considered provisional before they can, in the future, be subject to evidence-based interrogation. Marcie Laird explores the mediation of remote health information sharing between midwives and rural pregnant women during the mother's first pregnancy (Laird, 2021). These include visual aids intended to increase patient agency during telling stories about their life experiences; interactive prompts intended to develop a shared understanding of the determinants of a patient's social and emotional health; and the creation of self-reflective images intended to increase the validity of information shared between visiting midwives (Laird, 2021). Laird used what he learned from his involvement in this investigation to articulate ten principles, including the following three.
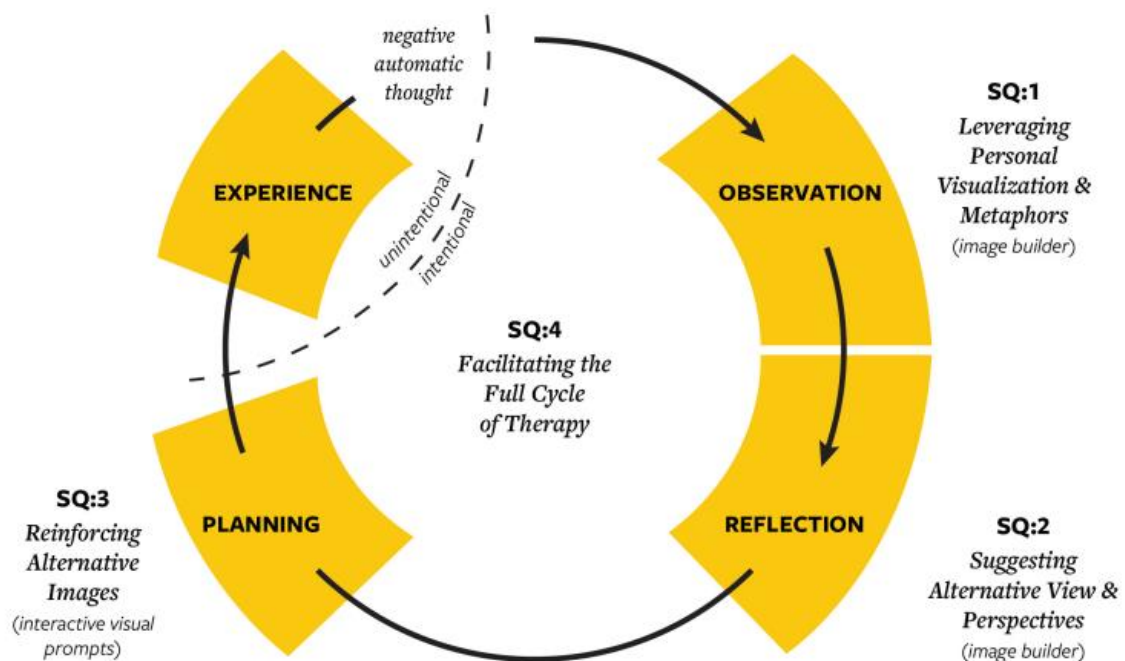

Figure 7: Anderson's investigative model (2020, pg. 19). "SQ" refers to a subquestion. Observation, reflection, and planning are stages in the cognitive behavioral therapy cycle with corresponding features in an imagined system.

1. Visual disclosure: The formal quality of visual aids influences the perceived privacy of the information embedded in them.
2. Collaborative presence: In shared digital spaces, participants' use of visual tools is influenced by their collaborators' perception of presence.
3. Visual appropriateness: The form of imagery used to mediate dialogue should reflect the tone and content of the information being shared. (Laird, 2021:13)

The first principle of "visual disclosure" relates to building trust as follows.

> "Abstract visual aids give the user a greater sense of control because the true meaning is difficult to ascertain without additional explanation. As participants, they can make discretionary disclosures, making decisions about what is included in the drawing and

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what is not included. For example, when patients create a cognitive map of their support network using emojis [here Laird refers to the previous image], this representation of their life is unquestionably derived. Their choice of emoji still carries information about their perceptions and emotional attachments, but this data is essentially inaccessible to midwives without explanation […], creating a sense of security for participants.

"On the other hand, as the images approximated a more realistic impression of the participants' lives, the window of interpretation narrowed, reducing their sense of privacy. The photographs used to perpetuate memories between the patient and his partner [other person mentioned here] reveal all the intricacies of their reality, making it difficult to "hide" behind abstract shapes that confuse intent. These images demand a higher level of vulnerability on the part of participants, where they actively choose to sacrifice privacy in favor of a more accurate representation of themselves. If a participant is asked to disclose information they consider private too soon, their relationship with the caregiver may suffer. Therefore, the relationship between the form of a visual tool and information disclosure must be carefully considered when using an image as a dialogic mediator." (Laird, 2021:51-53)

Design principles are thus general in nature but explicitly linked by the designer with specifically contextualized design exploration examples. Even beyond the derivation of principles, the study can be put into practice when anticipating use in research in the social sciences. Matthew Lemmond seriously explores virtual reality (VR) games as a platform to help cancer patients reduce their psychological distress, especially by making use of the metaphors contained (Lemmond, 2019)). A review of the literature provides patients with an authentic conceptualization of cancer (Harrow et al., (2008:339). One sub-question prompts exploration of the quality reported by such cancer patients, giving shape to the data in the new context of VR (Lemmond, 2019). It includes features visual (e.g., roundness, possession of appendages) and locomotor (e.g., malleability) The resulting theoretically based representational recipes can easily be adopted by researchers in the social sciences when they conduct experiments to determine how cancer representations might feel more intuitive to subject, or for adoption as a standard for applied research on the effects of certain VR interventions with cancer patients. Thus there are many ways to increase practicality. Focus, transferability, and practicality are achieved in a joint effort through research questions, investigative models, and design principles derived from the study Criteria described here address the subjectivity inherent in the exploration of design, harnessing the inherent strengths of the designer while guiding design activity systematically and rigorously.

Prerequisite student experience

The thesis project in NC State's Master of Graphic Design program requires student competencies implied in the program objectives. These objectives include:

- students will demonstrate a depth of knowledge of emerging technologies and related design issues through a collection of speculative, propositional, and inventive studio-based work.
- Student work will demonstrate knowledge of the consequences of student designs within and between social, cultural, and technological systems and for users in their physical activities.
- students will acquire design research methods that support collaborative work and involve people.
- students will apply existing theoretical frameworks from a variety of disciplines, including design, and assess their suitability for designing research and investigations.

- students will demonstrate knowledge of precedents and modes of inquiry from design and related fields in their studio work and writing.

Meeting these goals—and thus the thesis itself—depends on a course and a well-established institutional infrastructure. The thesis preparation course in the third of the four semesters facilitates the definition of the student project parameters. Students leave this course having written three of the five chapters of a thesis document: Introduction, Problem Space, and Investigation Plan. In their final semester, students engage in design exploration in the form of visual and interactive studies, guided by research questions and investigative models, and they write the final two chapters of the thesis document: Study and Discussion. Each chapter and document section has a recommended word count (6,000–12,000 words in total). Throughout direct work on the thesis, students meet regularly with the chair of their respective thesis committee and occasionally with a full committee of three graduate faculty members. This shared support system and schedule are invaluable.

Students must be capable designers, and this is ensured through admission, an intensive three-studio sequence, and a Research Methods in a Design course. This methods course covers human-centered design and user experience, roughly representing the best practices of normal design. The New Information Environments course covers the social and disciplinary implications of current and emerging technologies, while also broadening students' writing skills. The Conceptual Framework for Designers course organizes the knowledge base in the literature into theories of doing, thinking, feeling, and meaning; introduces students to a literature review; reveals the underlying structure of academic writing in the social sciences; and requires students to synthesize literature into a framework. These courses are fundamental to students' ability to generate problem statements, justifications, conceptual frameworks, and principles. The thesis preparation course builds on familiarity with the structure of academic writing to help students frame research questions and build investigative models. A series of short workshop exercises are given to students who wish to begin defining their thesis in the summer before their final year. Some of these exercises are also incorporated into the thesis preparation course. The graduate faculty who serve on the thesis committee and oversee prerequisite courses all maintain research practice. They recognize much of the literature students find through searching, and can suggest further literature or recommend strategies for finding it. North Carolina State University is a "very high research activity" doctoral university (Carnegie Classification), and as such has a robust library system with digital access to most academic journals. Without such access, this model of design inquiry would not be achievable, suggesting that design-based invention can only be one model among other design master's programs, as many degree-granting programs do not have the same resources.

4.   LIMITATIONS AND FUTURE RESEARCH

Design cannot be overly prescriptive, but the exploratory design must be rigorous if it is to play a role in evidence-based investigations. The academic model of design inquiry described here places the exploration of design within the broader theory development cycle, while other models tend to exclude design or assume it can survive a full cycle. Placing a design within evidence-based social science investigations makes design important for a wider range of activities and goals in academic settings. Of course, compelling arguments can be made for other models of design research and other conceptions of the place of design in the wider practice of inquiry. Each model will have its advantages and limitations.

Role design-based discovery scaffolding for designers in the social sciences. It retains what is inherent in design as a production practice of exploration and abductive reasoning (Martin, 2009:74), while also demanding that designers adapt their design explorations to knowledge structures in the social sciences and produce results that are conducive to further investigation of variables, not single solutions. . Deriving principles from work requires induction or reasoning

from the particular to the general. Designers have learned to think inductively, particularly in criticism, and are well prepared to make such contributions. If designers do not in some way adapt to other research paradigms—without, of course, ceasing to be designers—they cannot easily contribute to ongoing knowledge generation if it does not occur across disciplines.

Certain features of design-based invention differentiate it from solution-based design activities while aligning it with research practice in the social sciences. First, designers discover and interpret ideas and frameworks from the literature that are not limited to design. Following an efficacy assessment for an existing project, the designer synthesizes information sources to construct or define an investigation. Concerning the outcome and means elements of the research question discussed earlier, inquiry as defined can be thought of as an outcome-means construct, which is based on knowledge from multiple disciplines. From this point on, the designer engages in normal design (i.e., best practice design activity), generates a series of "supposed solutions" (Cross, 2006:72), and may, but does not have to, make a formal decision to develop a prototype. Thus, the exploratory phase represents the expansion of the possibilities, while the optional prototyping phase represents the contraction or closing of the possibilities. Finally, in deviations from the normal design, the principle is derived from the presumptive solution, not the solution. Through the rigors of design-based invention, these principles maintain a link back to the established knowledge on which the endeavor is based. Because there is continuity from the literature to exploratory forms of design, studies — both iterations and abandoned directions — become objects of boundaries (Star, 1989:37), interpreted in different ways by disciplinary communities. It is through these boundary objects that experts in other disciplines can see possibilities even the designer ignores.

A design inquiry model has been described in which design exploration serves as the discovery phase of the research. This model guides design activities to make specific contributions to areas of the social sciences that are outside of design. It involves a careful process with six investigative components, all ultimately connecting the knowledge base beyond design to design exploration. This model is modest in placing the design activity within the broader practice of evidence-based research. There is no claim that a designer's self-reflection equates to a strictly social science method. Design researchers must continue to study design and build on their knowledge of the discipline, but this does not mean that designers also set themselves apart from other important areas of inquiry that are highly valued at research universities.

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