Handbook of Design Research Methods in Education
Innovations in Science, Technology, Engineering, and Mathematics Learning and Teaching
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Investigating the Act of Design in Design Research

Publication details
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Published online on: 19 Jun 2008

Accessed on: 04 Sep 2023

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Part 6

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The Road Taken

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Design Research is a Complex, Practical, and “Wicked” Journey

This chapter investigates the roads taken and not taken in the LiteracyAccess Online (LAO) design research case (see Bannan-Ritland, 2003). LAO was designed to help adults help children with reading difficulties. This project revealed the complex and practical aspects of design in balancing constraints, trading off one set of requirements with another, and dealing with ambiguity and heuristics where design details often emerge only after narrowing down the design alternatives (Preece et al., 2002; Spillers & Newsome, 1993). The continual redefinition of constraints and the generation of new goals in the design phase highlight how pragmatic, dynamic, and generative processes are integrated in design research.

The acts of design in the LAO project detailed an attempt to balance the tensions of the theoretical and the practical. Nelson and Stolterman (2003: 49) discuss this tension by distinguishing between reactive and proactive stances in design by “... ‘finding meaning’ in things that happen and ‘making meaning’ by causing things to happen.” It is clear from the decision making and judgments made in the LAO design research case that the theoretical and practical issues of design are intertwined and interdependent.

Linking the theoretical and practical aspects of design research to the required complexity of problem solving aligns this form of inquiry with Rittel and Webber’s (1973) description of “wicked” problems. Nelson and Stolterman (2003) interpret Rittel and Webber’s description of “wicked” problems for design as: (a) not being formulated exhaustively in systematic terms, (b) addressing them as statements of a solution, (c) not being true or false and not possessing an exhaustive list of functions, (d) containing many explanations, (e) requiring unique, effective, single solutions that have no immediate or ultimate test, and (f) demanding that the problem-solver not make a mistake and avoid significant problems that could occur.

Designing and testing school and classroom-based interventions, like LAO, certainly reflect the described characteristics of a “wicked” problem in attempting to generate, address, and diagnose teaching and learning issues and solutions. Many of the learning issues embedded in LAO cannot be articulated fully, involved multiple variables, and potentially could be explained by many possible factors. The challenge in design research seems to be how to provide a warrant for the selection of the intertwined design and research decisions, all of which are not made purely on a theoretical or an empirical basis. Indeed, employing design research to address the complexity of teaching and learning environments can never address exhaustively all of the theoretical or empirical possibilities and typically involves a unique, highly contextual problem that is
difficult to evaluate and even more difficult to generalize. Most importantly, because all the related issues of a particular social problem in education cannot be dealt with, design research involves instances of practical, political, and other types of decision making and selective judgments to reduce the complexity of the issue to address manageably the acts of design and research (Nelson & Stolterman, 2003). The design decision making made in LAO highlighted the many directions that were possible and demonstrated the selective judgment used to deal with this “wicked” and complex problem. Multiple factors as described below, not only theoretically- or empirically-based decisions, influenced the selective judgments in this case, suggesting that increased attention to and consideration of the nature and process of design may help to shed light on the formation of explicit procedures and processes for design research.

Introduction

The current state of design research in the field of education has been characterized as possessing a significant lack of agreement on the processes and procedures of this emerging form of inquiry (Kelly, 2004; O’Donnell, 2004). Agreement does exist among design researchers that uncovering and testing theoretically-based propositions are crucial in the design and development of educational innovations; however, there is no clear articulation about how many of these theoretical and empirical decisions are made in the context of design. O’Donnell (2004) raised significant issues about how research questions emerge in design research as well as how the researcher knows which question, of the many possible, to focus on and why. Similar questions were raised in the same article concerning the implementation of theoretical constructs in design, such as which design features were selected for the implementation of a theory, again from the many possible, which were not, and why. These questions point to the possibility that other factors may be involved in clarifying the procedures of design research. We will re-examine the role and emergence of theory in justifying decision making during the process of design research.

Design research inherently involves the act of design. The process of design research subsumes many of the characteristics and processes representative of the nature of design as described by Lawson (2004), including locating relevant information, structuring a problem, exercising creative insight, proposing a solution, and evaluating that solution. If design research subsumes the act of design, then those involved in this work may benefit from using the lens of the design process to uncover the decisions and complex judgments made in design research.

In this chapter, we propose to accomplish four goals:

1. Reveal the complexity of the decisions and judgments made during acts of design in design research.
2. Uncover how the process of design research unfolds; specifically, which design roads are taken and which are not, as well as which research questions and methods fall from this work and at what points.
3. Illuminate factors in design research that may contribute to, influence, and propel the process forward.
4. Highlight the broad themes related to the nature of design that were uncovered in this analysis.

We will accomplish these goals by expanding upon a previously presented example of design research, LiteracyAccess Online (LAO), a web-based technology system that
provides support for teachers, tutors, and parents (literacy facilitators) by addressing one of the most important goals for all children—developing literacy skills—with particular focus on those with disabilities (see http://literacyaccessonline.org). The goal of the intervention is not to teach literacy skills in a didactic fashion. It is to offer a technology-based environment that supports both helping literacy facilitators and children as dyad.

The LiteracyAccess Online research project is described through the phases of the Integrative Learning Design Framework (ILDF). The ILDF presents a multidisciplinary and complementary blending of perspectives on design and research (see Bannan-Ritland, 2003) and provides a structure within which to position design problems, selected methods, and design moves at different points in the design research process (see Figure 15.1). Previously presented descriptions of LAO as a case example of design research were constrained by the space requirements of the academic journals in which the articles appeared; therefore, in this chapter, we relate much more of how the decisions and judgments were made and their impact on the emergent theory. Significant focus is placed on how the LAO design research team interpreted and framed design problems through progressive research questions and methods. These and other factors prompted design moves that revealed different design problems. By employing a design process lens, this examination of the road taken and those not taken illuminates the many factors, decisions, and judgments that may prompt and influence the process of design research.

In our examination of the LAO design research process, the following four broad themes emerged, which will be addressed more fully in the discussion section of the chapter. Design research:

- Encompasses a complex, practical, and “wicked” journey.
- Involves multiple decision–evaluation spaces that are manifested in problem states, design moves, and the framing of the design problem.
- Is an interpretive, social and multidimensional process.
- Involves many factors that prompt acts of design and reinterpretation of theory.

The emergence of the research questions and the selection of the methods in design research are intertwined inexorably with the act of design. Examining the inherent acts of design and what prompts these acts in this case example may shed light on and clarify further theoretical and research decision making—or the complexity of the road taken in design research.

Research Questions and Methods

The Informed Exploration Phase

The goals of the informed exploration phase in the ILDF are: (a) to identify, describe, and analyze the state of the problem or phenomenon, (b) to generate initial theoretical perspectives about how people learn and perform, and (c) to identify the corresponding design directions. Although not necessarily a linear process, we have attempted to delineate a rough sequence of the design actions that we engaged in throughout this phase. In this initial phase, the team was charged with the broad, general, social goal of how to provide literacy support for children, particularly those with disabilities. An early research question that evolved from the design team’s collaborative interaction was: “What are the best practices in basic literacy acquisition for fourth- through
Figure 15.1 Questions and Methods for Design Research by ILDF Phase.
eighth-grade students with or without disabilities and what opportunities exist to provide technology-enhanced literacy support for this population? To address this question, the team borrowed from and integrated methods employed in product design, performance or needs assessment, and usage-centered design, as well as traditional literature review techniques. These methods were particularly useful for the primary phases of design research: namely, to locate the problem; to integrate practice, theory, and research perspectives in literacy and technology-supported learning; and to work toward the generation of initial models to enact in design.

Needs Analysis

Gap or needs analysis is a traditional technique used to begin instructional design; it involves identification and documentation of the current state and the proposed ideal solution. Typically, this type of analysis is conducted from a problem-solving orientation that starts by articulating the problem and solution clearly; however, in education, this process does not traditionally involve market analysis or benchmarking techniques. Benchmarking is an evaluation method that involves gathering information about other companies’ or organizations’ best practices to inform one’s own practice (Barksdale & Lund, 2001). Given the proliferation of software tools that address the reading and writing processes, the team elected to capitalize on marketing and benchmarking techniques to examine many examples of the literacy software then available. Practical decision making drove this investigation in the team’s desire not to “reinvent the wheel.” Therefore, early in the life cycle of the project, existing literacy software programs were reviewed and analyzed in order to identify instructional gaps in the marketplace and to provide benchmarking of competitive products as a rich source of ideas for potential designs that would have utility beyond their publication in research papers. This effort resulted in a broader understanding of the landscape of literacy software design and identified gaps or needs that existed in the marketplace.

Following this exploration, design ideas related to variations on tutorial-based support of children’s reading processes that seemed more prevalent in the marketplace were investigated initially. Unexpectedly, an important team member, who was also a parent with a child with a disability, argued for the importance of providing support for the literacy facilitator (as well as the child) in the collaborative reading process. She emphasized her practice of reading with her child, rather than children reading solely on their own, and her desire for resources to improve her interaction with her child. Her insight prompted a major turning point in the team’s design direction. This resulted in a design move or decision away from child-centered, tutorial-based, literacy practices to supporting both the facilitator or tutor and the child in a collaborative literacy process. This design move was based primarily upon the interests of someone involved in the project and upon a parent’s insights and needs related to her reading practice with her own child. These initial insights were affirmed by interviews with other parents and experts, which suggested a gap or need that had not been addressed yet by commercial software developers or research involving technology support. This design move was made for both political and pragmatic reasons to fill an identified need. This decision changed fundamentally and defined further our design problem state and goals. The decision also restricted the type of research questions and methods that we could now ask because a goal had been established to design for collaborative literacy exchanges. This design move, or “road taken,” placed new constraints on the emergent theory and design and eliminated other design research directions such as investigating individual, tutorial-based, literacy support and nontechnology or whole classroom-based, literacy support.
Once the need for collaborative support of the literacy process had been identified and established, the next step was to conduct a review of the literature to clarify the learning processes, skills, and techniques employed by both literacy facilitators and children while they were reading. At this stage, our questions were focused on what information could be gleaned from the data or literature that provided insights into the tutoring or facilitation processes and what reading strategies for children with or without special needs could be located in previous research. Sources included the National Assessments of Educational Progress’ reading achievement levels for the United States, a comprehensive study detailing the demographics and skills of Literacy Volunteers of America, best practices in reading and tutoring strategies, and studies related to the needs of students with physical, emotional, sensory, or cognitive deficits in the reading process, among others (e.g., Gambrell, 1999; Grossen, 1998; Mastropieri & Scruggs, 1997; National Assessments of Educational Progress, 1998; Simmons & Kameenui, 1998). Synthesizing these resources informed our efforts and allowed for integrating our theoretical approaches with the practical theories espoused by parents on the team, as well as expanding our notion of the collaborative process of reading and tutoring, which would continue to evolve as the design research progressed. The resulting design move was to integrate some established collaborative reading practices into the technology environment and to generate others. These decisions further solidified the convergent processes of design that shifted the design problem space toward determining more specifically how to support collaborative literacy exchanges.

After reviewing the market demand and research literature related to the collaborative reading process between facilitators and children with or without disabilities, the research team was ready to examine specific learners’ (represented by a facilitator and a child) needs more closely. In line with needs assessment and performance analysis procedures recommended by Rossett (1999), focus group interviews were conducted with the parents of four struggling readers. Essentially, the first cycle of focus groups was conducted to answer the question: What are the baseline skills, experiences, and perceptions of novice (or untrained) and expert literacy facilitators? The results were scrutinized for reading activities that parents undertook with their children, specific reading strategies used, feelings of efficacy about assisting their child in the reading process, and current partnerships that exist for facilitating reading, both inside and outside the school environment. In addition, surveys were used to solicit information from literacy and special education experts on effective literacy activities and strategies, what to avoid in one-to-one reading sessions, and their perspectives on the characteristics of good literacy facilitators. These methods of gathering and analyzing data provided a more elaborated understanding and definition of the design problem, as well as the targeted audience members, their experiences, the knowledge level of both the child and the facilitator, and how they worked together. This in-depth, qualitative exploration provided a solid foundation for the team’s subsequent design moves to address collaborative literacy and assistive technology support from the strong position of having observed the phenomena directly.

**Audience Characterization**

The above analysis also expanded dramatically our notion of the “context” of the collaborative reading process and determined that we needed to address much more than simply a parent reading with a child. The informed exploration phase emphasizes
the investigation of contextual factors of influence that may impact the emergent theoretical model situated in a specific environment and the consideration of factors that may impact the eventual diffusion and adoption of the design. The question for the LAO project now was: “What were the social, cultural, and organizational influences on the literacy facilitators who were attempting to support children with or without disabilities in the reading process?” It was at this stage that the inherent complexity of the instructional problem involving multiple target audiences was first revealed. As an initial step (which was incorporated in later cycles also), the team identified and interviewed representatives of many target audiences such as parents, children in the fourth through eighth grades with or without disabilities, teachers, reading specialists, special education personnel, and literacy tutors in order to create audience profiles. This analysis focused specifically on the collaborative reading process between children and literacy facilitators identified earlier, and it revealed a broad range of experience levels and disabilities as well as the inherent complexity of designing for the necessary interaction between the multiple combinations of facilitator and child. The applied methods used in this analysis included role modeling, as part of a usage-centered design process (Constantine & Lockwood, 1999), and the development of personas (Cooper, 1999), based on direct experiences with the target audience members. Role models or personas are similar to the creation of vignettes that strive to capture the substance of a setting, person, or event to communicate a central theme of the data but do not represent real life directly (Graue & Walsh, 1998). Profiles generalize audience analysis information from multiple interviews and observations. They became the focus for targeted design concepts. In this case, profiles described struggling readers.

Analyzing the interview data and crafting personas brought to light a new design problem. It was paramount to think carefully about furnishing a consistent supportive environment for children who at different times may read with parents, siblings, teachers, reading specialists, and tutors, as well as accommodating a broad range of reading levels and disabilities. Consideration of the social, cultural, and organizational contexts (such as the intersection of school and home environments) led the team to define further the theoretical design concept or direction as one that provided simultaneous assistance to facilitators with varied levels of experience and access to the child’s progress by multiple facilitators in order to support the child’s needs better. These design moves resulted not from preconceived theory but from direct experience with individual and combinations of target audience members, analysis of the context of performance, and close investigation of the potential intersections of collaborative exchange among the participants. The integration of existing theory, research, applied practice, and contextual information about the task did generate a unique theoretical position for promoting high-level, collaborative literacy experiences incorporating reading strategies and assistive technology, which are detailed in the next section.

The Enactment Phase

In the enactment phase, researchers operationalize what has been learned in the informed exploration phase into an intervention or a design that articulates the theoretical model, allowing for feedback and iterative revision of the emerging model and design. Although this process is depicted linearly, in reality it is much more ill-structured, chaotic, and heavily reliant on social negotiation. Participatory design methodologies were used in the LAO research to clarify and communicate the conceptual design and research direction to all team members and, at times, to different teams. This phase occurred through progressive intensive brain-storming and planning sessions. These
sessions required the participation of: (a) members of the design research team at various levels and at different times, (b) involved funding agency representatives; (c) project investigators, (d) content experts, (e) graduate research assistants, (f) parents, (g) teachers, (h) children, and (i) other school support personnel. Although intense and conflictual at times, this collaboration was crucial to the design research and to the collective learning of all who participated to progress LAO forward.

Research/System Design

After identifying the general direction of providing simultaneous support for various combinations of literacy facilitator–child dyads in reading strategies and assistive technology in the informed exploration phase, the design research team was ready to attempt to solidify better the emergent theoretical grounding or framework by establishing initial theoretical conjectures. A theoretical conjecture is a theory-based inference based on related practical experience, literature, and previous studies that expresses the content and pedagogical dimensions or focus of the designed intervention (Confrey & Lachance, 2000). Documenting inferences for learning processes requires moving from the creative, implicit, generative design process to the explicit, systematic, and often reductionistic process of presenting the suppositions or assumptions in writing in order to communicate them clearly to others. The LAO research team did not articulate these assumptions formally until later in the design research cycle. Our assumptions were embedded implicitly in the evolving prototype and were discussed frequently; however, it was not until later cycles of the design that we were able to articulate them fully.

We elected to ground our theoretical conjectures or design assumptions in a sociocultural perspective of learning that ultimately would inform the design and development of the technology system. This pedagogical perspective was assumed in our selection of later methods and tools, and it seemed to align well with the design direction of supporting the complex interaction between parents, teachers, tutors, and children with and without disabilities in the multiple contexts present in the collaborative reading process. It is important to note that this pedagogical orientation was not formed before determining the design direction; rather, it was selected after the informed exploration phase as a good fit to complement and expand our theoretical notions of collaborative literacy exchange.

Selecting a sociocultural perspective on learning prompted us to think about the alignment of our conjectures about learning with this orientation. Initially, these assumptions were implicit; gradually they became explicit and usable. Eventually, they were combined and stated in this primary conjecture: by providing a consistent environment, access to assistive technology, and reading support strategies for both members of the dyad, the facilitator and child will engage collaboratively in higher level literacy processes. Although this theoretical conjecture provided some initial direction for our design, it was not specific enough to inform our detailed design. Over time, the team was able to transform this broad statement into more well-defined learning or performance targets with some established criteria, while attempting to adhere still to the established assumptions and theoretical orientation (McMillan & Schumacher, 2001; Nitko, 2004). Ultimately, the following learning targets were articulated:

- Literacy facilitators (represented by parents, teachers, or others) will acknowledge the importance of and demonstrate their ability to implement research-based reading strategies when provided with technology-based support in a collaborative reading session with a child.
• Children with or without disabilities will demonstrate their abilities to access information, activities, and assistive technology support related to reading as well as to interact with literacy facilitators in a collaborative reading session.
• The facilitator–child dyad will be able to explore and select appropriate assistive technology integrated with internet-based supports that can facilitate performance in reading and writing.
• Children, regardless of their disability, will be able to capitalize on technology-based supports and a collaborative process to improve their literacy skills.

These evolving learning targets directed the system design and integrated research process of the LAO project and provided a basis for assessment and evaluation. Many design sessions would take place before we were able to identify a framework that could move our integrated research and design efforts forward substantially.

Articulated Prototype

In line with Dabbagh and Bannan-Ritland (2005), the team aligned the design research conjectures or learning targets with existing pedagogical models, where possible, in order to ensure a grounded design. Similarly, Bell et al. (2004) describe identifying design principles that can be interpreted to inform instructional activities or guide empirically- or theoretically-based design. Rather than generating a totally new design framework or principles, the team looked first to pedagogical models that seemed to provide a good fit and alignment with the existing theoretical design directions. We took advantage of the fact that one of the team members was an expert in activity theory, which guided our analysis of instructional and performance tasks.

The task analysis technique based in activity theory was applied to the LAO project to elaborate the types of instructional tasks and supports that might be incorporated into the theoretical design (Jonassen et al., 1999). The original conjectures, identified learning targets, and revised elements for evaluation were in alignment (see Figure 15.2). The task analysis of the learning targets isolated and explicated the interaction among the components: (a) a subject, the facilitator–child dyad, (b) an object, the LAO system, (c) the tools, literacy strategies, assistive technologies, (d) the division of labor, the division of tasks between the facilitator and the child in the reading process, (e) the community, facilitator–child dyads are members of school, home, and tutoring communities, and (f) the rules, the social norms, relationships or constraints that guide the collaborative literacy process. The identification of, and interaction among, these elements shaped the resulting evaluation procedures, as well as informed the theoretical model of collaborative literacy that was embedded subsequently in the instructional innovation.

Detailed Design

Clarifying the cognitive and performance processes or tasks inherent in the design is crucial for creating and testing a theoretically-based innovation. We found that activity theory captured the interactions between the facilitator–child dyad across context more richly than traditional, hierarchical, task analysis. In the LAO design study, the design problem and our questions at this point were exactly how we should operationalize the cognitive and performance tasks identified in the task analysis related to web-based technology in order to promote rich, higher-level interaction between the literacy facilitator and the child when they are reading together. We elected to generate a design...
Figure 15.2 Progressive Formulation of Conjectures to Local Evaluation Questions for the LAO Project.
structure that aligned with elements of activity theory using a usage-centered design process (Constantine & Lockwood, 1999) that would assist the enactment of our emerging model of collaborative literacy processes.

To address the problem of explicating features and functions, we identified some prescriptive design models that structured the many levels of users and complexity in our theoretical model. The team decided that the challenge of constructing a technology-based environment that improved both the literacy facilitator’s guidance and the children’s reading aligned well with an electronic performance support systems (EPSSs) design approach (Bannan-Ritland et al., 2000). Originally, EPSSs were conceived as integrated electronic environments that are immediately accessible to learners and provide for dynamic communication akin to the productive exchange between a master and an apprentice (Gery, 1991). In addition, an EPSS design could embed the theoretical assumptions of a sociocultural perspective on learning and activity theory by focusing on the creation of a technology-based object incorporating various tools to support the performance of and exchange between facilitators and children while they are engaged in the “work” of reading. The synergy between the EPSS design approach and activity theory also permitted investigation of the multiple social and contextual issues (or the intersection between the subject, object, tools, division of labor, community, and/or rules), providing an important alignment between our theoretical stance, design principles, and evaluation efforts (see Figure 15.2). Much of this alignment was not apparent and explicit immediately; only upon retrospective analysis does the clear alignment of the theory, the design, and the evaluation reveal itself fully. This level of clarity about the cognitive and performance processes was reached after many sessions where ideas ebbed and flowed—and stalled many times—during four years of design and revision cycles and problem-solution states.

The design problem revealed in this phase was how to embed into the theoretical model the features and functions that would comprise the interface that would allow for cycles of evaluation or testing of the theory. Providing opportunities to evaluate, or give feedback on, the expression of the theory in the design seems crucial to the validity of the research. Therefore, we used flexible techniques that allowed the team to provide feedback many times and in many ways on the expression of the theoretical model and our corresponding assumptions of support of, and collaboration in, the reading process embedded in our design. Opportunities for feedback on the initial designs were facilitated through a usage-centered design process by the creation of use cases, task models, and content models, culminating in the development of a prototype. Paper-based prototypes allowed for flexibility in making conceptual changes and permitted a modeling process that allowed the interested parties to document, validate, and communicate about theory. Through participatory design practices, various members of the team were engaged in what Schön (1983) referred to as a shaping process where the current design state “talks back” to the team and each major design move or combination of moves contributes to reframing the design problem.

In the LAO project, use cases, task models, and content models were generated and revised to develop technology-based performance support for the literacy facilitator to have immediate access to research-based, reading strategy information while reading with the child. Training and information on assistive technology modifications (text-to-speech, enlarged text, etc.) were provided to the facilitator as additional support for the struggling reader with disabilities, based on the results from multiple cycles of design and feedback on the abstract prototypes. Ultimately, the team operationalized the cognitive and performance processes of supporting the reader and the facilitator in a collaborative guided approach to reading through the provision of interactive, online
reading activities, with feedback for the child and progress reports shared by multiple facilitators. Experts and representative learners alike reviewed learning targets, task analyses, initial design concepts, system-level architecture, and detailed design templates at several points during a single cycle. Data from these reviews ranged from determining to what extent the design embodied the theoretical model to, more commonly, general reactions to the interface, look, and feel of the features presented.

The challenge of the participatory design process should not be understated because it involves social discourse processes in an environment where both innovation and efficiency are being encouraged simultaneously. Modeling the interface using the flexible methods of usage-centered design encompassed many prototypes as well as many microlevel design problems and moves, which translated our theoretical assumptions about learning into a pragmatic design. Such documentation supports designers at all levels.

The Local Impact Evaluation Phase

In the evaluation phase, decisions at the local level are only as good as the focused planning and forethought of what exactly to evaluate. The LAO project progressed through multiple cycles of evaluation, focusing first on the usability and validity of the intervention designed for the users and later on evaluating its impact on learning. Some of these evaluations were informal, whereas others encompassed more formalized studies; however, the cycles of evaluation and revision built upon one another to improve the theoretical model embedded in the design.

Formative Testing

Design-based research is characterized by iterative cycles of design, enactment, and detailed study that have been represented as ministudies or microcycles (Bell et al., 2004). These microcycles take place throughout the design research process but are essential in the evaluation phases for uncovering the local validity of the enacted theoretical model or design and the usability or fit of the innovation for the context. During this phase in the LAO project, the research questions were centered on how to ensure that the design was usable and effective and that the enacted theory of design had internal validity or relevance to the potential target audience and context. In this time-intensive phase, the research team employed methods based primarily on usability testing and formative evaluation processes (Rubin, 1994; Tessmer, 1993).

The LAO project progressed through several iterative microcycles of development, usability, and formative evaluation testing. Each microcycle could be characterized as a problem state and a subsequent design move. In this project too many microcycles occurred to describe them all adequately here. The overall purpose of these multiple microcycles of testing usability and other factors was to reveal major and minor weaknesses in navigation and in the interface, prompting data-driven changes in format and functionality. In addition, a series of expert reviews and one-to-one, small group, and field-testing were implemented in progressively more authentic settings. Qualitative studies characterized the target audience’s interaction with the enacted theoretical model in relation to the learning targets. Specifically, the team was interested in how the facilitators and the learners perceived and interacted with the web-based support in the collaborative literacy process (which included both reading and writing tasks). Initially, a pilot study comprising five dyads of mostly parent facilitators and one sibling facilitator was conducted that simulated some of the tasks in LAO and provided feedback on
the emerging site. The methods included collecting data through semistructured interviews and observations of parent–child interactions with the prototype and the complementary assistive technologies (e.g., text-to-speech, etc.) that promoted reading and writing activities.

**Theory/System Refinement**

The preliminary study revealed that the children were motivated to complete reading and writing activities on the web and that the facilitators developed awareness for implementing reading activities in a collaborative process but desired additional support for the children’s disabilities. Although the web-based activities and supports for the reading process were useful for providing more authentic and self-initiated reading and writing activities, the research also revealed that interactions between the parent and child dyads during these activities often created tensions that were not present when the children were working with nonfamily members. Revisions to the use of behavioral prompts directed toward the parent–child dyad to release tension (such as prompts to take a break, positive reinforcement techniques, etc.) when engaged in collaborative reading and writing tasks and additional reading strategy supports and activities.

A follow-up qualitative study was conducted with eight parent–child dyads who represented a variety of skill levels and disabilities (Jeffs, 2000). The goals of the study were: (a) to identify the characteristics of the parent–child dyads working together, especially in literacy skill development, (b) to depict the interactions of the dyad, and (c) to investigate the impact of various forms of technology (internet, EPSS, and any assistive technology) on the attitudes of the participants. The participants included parents and children with various disabilities in grades four through six who were reading at least two grades below their expected level and who tended to avoid reading and writing tasks before they joined the study. The study revealed that the parents recognized the importance of immediate feedback and the assistive technology features in the tools provided. Other results showed that, with the support of their parents, children can select appropriate technologies and that with integrated use of the internet and assistive technologies, children’s writing samples improved in both quantity and quality. As a result LAO was revised to include text-to-speech capabilities and reading selections reflecting varying abilities and areas of interest.

At this point, traditional research and design processes diverge somewhat in that the analyzed results are not an end in and of themselves but are used for data-driven decision making or problem solving to build upon or revise the theoretical assumptions and improve the design. Often, based on testing results, we would need to throw out previous prototype features and totally redesign, revise, or add new features. The team’s informed design judgment and collaborative social negotiation were keys to this decision making.

**Evaluate Results**

Testing the intervention in progressively more realistic settings provides valuable information to inform theoretical assumptions related to the design and also to begin to identify variables that might be tested further empirically. Conducting additional research to investigate further the collaborative process promoted by the technological environment as well as to isolate the effects of the multiple reading supports and assistive technologies afforded by the prototype remains an important objective.
Although LAO’s funding cycle has ceased, in order to progress from local effects to more externally generalizable effects, additional testing cycles are needed to isolate and test particular variables using multiple sites, diverse participants, and settings progressively limiting the researcher–participant interaction. With more funding, additional data collection is necessary using selected measurements, online surveys, and interviews with parents and children in homeschool environments, preservice teachers, and in-service teachers in several geographic locations where there are interactions with children with a range of disabilities. These data would provide additional evidence for the effectiveness of both the theoretical assumptions embodied in the collaborative reading and literacy process, as well as the prototype at its highest fidelity in the full context of the intended use.

The Broader Impact Evaluation Phase

Traditionally, academic publishing of research results was the final product of many isolated studies. The difficulty of addressing directly the systemic scalability and sustainability of educational interventions or innovations represents a current challenge for design research (Fishman et al., 2004).

Diffusion, Adoption, Adaptation

Although, at this point, we can only speculate what variables or factors might influence the problems of design diffusion, adoption, and adaptation, Rogers’ (2003) work on the diffusion of innovations provides an excellent starting point for what might be termed a “metadesign” move. Earlier phases of design research and the problem states-design moves associated with those phases can provide valuable insights into issues of relative advantage, compatibility, complexity, trialability, and observability (Rogers, 2003). In turn, this knowledge can be used to inform research questions and methods in the final phase of broader impact in many ways, such as using data collected from interviews with audience members in the exploration phase to suggest how the innovation might be perceived by users or participants as better than the current situation and thus promote adoption (relative advantage).

Attempting to identify attributes of the intervention related to diffusion and adoption in the early stages of design research may avoid issues of incompatibility, such as an intervention that does not align with school district policies or one that induces nonactor-oriented views of the transfer of learning (Fishman et al., 2004; Lobato, 2003). At the metalevel, design moves that attempt to engineer the receptivity of target audience members comprise the next frontier and challenge of articulating design research clearly.

Web-Enabled Proto-Diffusion

In the LAO project, the research team has scratched only the surface of the issues of scalability and sustainability. However, promising directions for diffusion and adoption are based on the collection of preliminary data from early participants engaged with the prototype intervention. For example, the LAO project consists of an open, database-driven site that allows the continual tracking of users who interact with the EPSS, forming a sophisticated method of identifying early adopters and their needs. The site assembles profiles of all its users and contains multiple structured and open feedback forms that collect data on the early adopters who locate and use it. Having an “open”
site across all the phases of design and development potentially gathers information about many of Rogers' (1995) attributes from a worldwide community, which may lead to insights into the theoretical model and design revisions, as well as factors related to the adoption and diffusion of this educational product.

Plans are in progress for implementing more complex, data-gathering methods that track in detail the literacy facilitators' and children's interactions with LAO through data-mining techniques. This initiative will be similar to current research efforts that trace students' actions (e.g., clicks, navigation paths, etc.) and responses, as well as participants' reactions or journaling in an electronically collected “log file” for extensive analysis (Buckley et al., 2002). As the number of sites and users of LAO expand and direct observational research activities become more difficult, a methodology that relies on an automatic, online, detailed collection of users' activities can produce interesting results for both theoretical model testing and diffusion purposes. The research team anticipates that these methods will answer questions such as: How do the members of the learning dyad progress through the web-based innovation over time and what components do they use? How do potential users discover the LAO system and how does it diffuse through identified social networks and communities such as schools, parent groups, homeschooling organizations, etc.? What factors are important to potential and actual participants when they consider adopting the system? How do the facilitators and the children use, adopt, or adapt LAO for their own needs? Massive quantities of data could be collected from the children and the literacy facilitators as they interact with the features and strategies embedded in LAO. These data, combined with the user profile information and quantitative and qualitative feedback, make it possible to search for significant patterns of use correlated with particular users. Based on multivariate adaptive regression and correlational statistics, data-mining provides the opportunity to identify associations and anticipate behavior patterns and trends. The exciting implications of this type of research are that it can provide unprecedented amounts of data and detailed information for analysis to inform the continual revision and diffusion of the educational innovation or to warn of unanticipated problem states requiring corresponding design moves.

Consequences

Most design researchers may aspire to the goal of systemic change, but remain rooted in the microcontext of individual classrooms, teachers, and schools. Fishman et al. (2004) attempt to bridge this gap by advocating studies that employ system-level variables such as adoption, sustainability, or spread and that focus on schools and school systems as the unit of analysis. Systemic change is the most challenging of educational objectives. At the very least, a thorough analysis and understanding of system-level policies and culture are crucial for informed design and evaluation. As an innovation matures progressively through multiple design research cycles, information about the school's or organization's culture, capabilities, policies, and management can be gathered to guide both the design and the later diffusion and innovation studies (Blumenfeld et al., 2000). For example, Rossett (1999: 30) advocates a systemic approach assessing performance or learning in the context of a performance system that “. . . comprises standards, feedback, knowledge, incentives, recognition, information, management, sponsorship, technology, tools, processes and more.” These factors can be analyzed in the early phases and then re-examined later to determine if the enacted design meets the learning targets and aligns with the established policy and cultural norms of the target system(s).

In the LAO project, the informed exploration phase revealed multiple target audience
members in different contexts of use. Each of these contexts of use presents a different social and cultural system with its own inherent policies and norms that may be examined for the potential adoption, adaptation, or diffusion of LAO. Potential questions related to this final phase of LAO may include: What are the perceptions of the target audience members (in different contexts of use) of the “fit” of LAO or its alignment with specific cultural, policy, and organizational structures? What drivers and barriers exist for the adoption and diffusion of LAO in each context of use (school, home, tutoring environment, etc.)? How do current practical, cultural, or organizational relationships contribute to the use or nonuse of LAO? Does use of the LAO system change current practical, cultural, or organizational relationships? What broad systemic factors concerning the scalability and sustainability of LAO can be identified to inform other design research?

Some of these results may be mapped to the assessment of this information in earlier phases to determine if there have been any changes in perception or emergent problems related to the use, adoption, or unanticipated adaptation of LAO. Methods such as logging computer activity, multisite interviews, surveys, observations, and data-mining techniques may provide ways to examine the interrelationships and complexity of the factors involved in the diffusion and adoption of an educational innovation both within and across individual contexts. Employing methods that can illuminate systemic-level questions and identify factors influencing educational changes constitutes the “meta” problem state, resulting design move, and the next major challenge for design researchers.

Discussion

Our retrospective analysis of the acts entailed in the design of LAO revealed that the decisions, judgments, or turning points that propelled this case of design research forward involved other factors in addition to the theoretical conjectures such as:

- practical considerations
- serendipity
- applied design techniques
- implicit, pretheoretical learning assumptions
- divergent and convergent research questions
- simplifying design options
- judgments of adequacy
- the design team’s prior experience
- prototyping and modeling methods that externalize understanding
- collaborative questioning and evaluation
- budgetary factors.

These factors prompted many important decisions and evaluations that spurred the design research forward or, in some cases, restricted or constrained the design efforts. Examining these factors also disclosed what was involved in the emergence and selection of the theoretical components, research questions, methods, and features for the design of LAO. The complexity of this journey is evident in the narrative of the LAO example and presents some broad themes related to the nature of the design process, which are discussed in the next section.
Decision–Evaluation Spaces, Problem States, and Design Moves

Our analysis of the design decision making, or the road taken, in the LAO design research highlights the cascade of judgments and decisions and provides a useful metaphor for examining more closely the many potential acts of design that embody theory. MacLean, Young et al. (1989: 247) speak to the selection of options and to providing a design rationale for their work in interface design in this manner: “To understand why a system design is the way it is, we also need to understand how it could be different, and why the choices which were made are appropriate.” These authors describe their consideration of the many alternative options in design as the “decision space” and the generation of explicit reasons for selecting a particular option from many possible options as the “evaluation space.” Viewing the design research process as involving emergent progressive decisions, spaces, or states provides a way to analyze when, where, and how multiple design ideas emerge and may provide the means to examine the selection and justification of those choices.

Similarly, Doblin (1987) characterized the design process as consisting of a current beginning state, followed by a design process that contains analysis, genesis, and synthesis activities, culminating in a different state. These states change and evolve dynamically as decisions are made and design paths are selected, and they may require different forms of analysis, decision making, and evaluation at different points in the process. These states can be described as different problem states that engender interpretive, evaluative, or analytical processes and then prompt corresponding design moves. Viewing design research through this conceptualization of the design process promotes a new way of examining design research as continually evolving problem states that incorporate multiple decision–evaluation cycles and result in specific design moves. Each design move impacts the ensuing problem state significantly.

Examining the decision making in the LAO design research revealed an overall pattern of analysis of problem states, decision–evaluation cycles, and corresponding design moves that resulted in the creation of a new design problem space, prompting the cycle to repeat itself once again and continuously throughout this four-year program of research. Knowledge of the decision making that occurred at different points in defining the problem state, evaluating the design options, and enacting a particular design move rather than the alternative promoted clarification of and necessary boundaries around what type of phenomena (e.g., collaborative processes of literacy) could be investigated logically. Revealing this complex decision making in design research provides greater insight into how the problem is understood, framed, and reframed, perhaps the most challenging and important determination in more general processes of design as well as in design research.

Design is an Interpretive, Social, and Multidimensional Process

If the most difficult part of design is to locate, frame, and describe the design problem fully, then it is complicated further by involving a team of people. As Coyne (2005: 5) states: “. . . problem setting is a contingent, fraught, and sometimes consensual process for which there is no authoritative set of rules, criteria, or methods.” Framing a problem and other acts of design rely heavily on interpretation and social negotiation. How we choose to see the problem, how we analyze or evaluate it, and what features are selected ultimately for a particular design embody interpretations or judgments of what pragmatic factors and aspects of theory are considered. Collectively, in team-based design settings, these judgments or interpretations need to be negotiated amid the different
interests and personal concerns that may be present in the design process. When negotiated successfully, design activity resulting from participation in team-based design can become the catalyst for a shared learning process that “...educates individuals and shapes the evolving choices simultaneously” (Liedtka, 2004: 14).

In the LAO design research, perspectives from the research team members, interested parties, and potential audience members were all brought to bear on the decision making that took place or the judgments that were made. Every iteration of the LAO design became an interpretation, and each design team member progressed further toward a more fluid, adaptive expertise or understanding of the collaborative literacy process as he or she participated in creating the evolving design (Winograd & Flores, 1986). This participatory design research experience represents a multidimensional process where a group of individuals are engaged in the individual interpretation and collective negotiation of framing a continually changing design problem as well as determining decision–evaluation cycles and negotiating design moves. Kelly and Lesh (2000) described a similar multilevel approach to research in their multitiered teaching experiment. However, additional layers of complexity are also evident in the design research process if we consider the many ways in which we might interpret and frame individually and collectively the dynamic problem states and many factors discussed in this chapter that may prompt the decision making or judgments at different points in a design process. Given this, the act of design in design research becomes a much more complex activity, with many layers of decision making and perspectives that may influence theory and design.

Many Factors Prompt Acts of Design and Continual Reinterpretation of Theory

Analysis of the LAO research revealed many factors that prompted acts of design, among them the pragmatic, theoretical, and applied influences on decision making. Some of these factors converged in the decision–evaluation cycles or the team diverged from existing information or approaches to attempt to promote new directions for research and design. This iterative process of convergence and divergence evident in the LAO design research and its influence on emergent theory present a final broad theme in this analysis. As an example of the convergent–divergent process, the formulation and selection of the initial research questions in LAO were based on merging existing, theoretical, and applied perspectives on collaborative literacy and then diverging from more typical, child-centered, tutorial-based approaches. The exploration of multiple options converging in a particular direction and departing from the traditional forms of design present in the stages of the LAO research created the foundation for the next cycle of design research activity and influenced future cycles heavily.

Other examples of the convergent–divergent process in the LAO design research included the convergence of a sociocultural pedagogical orientation and the applied design principle of EPSS design. Additionally, when a more detailed design direction was needed, the team members found that they were dissatisfied with the existing applied methods of task analysis and selected an alternative method based on one team member’s familiarity or prior experience with activity theory. With the selection of this alternative analytical tool, the team diverged from existing traditional approaches to task analysis to generate new features and functions of online literacy support that maintained alignment with our theoretical direction. Dym et al. (2005) refer to this process as alternating between convergent thinking that promotes deep reasoning and more creative, divergent thinking where the designer (or design researcher) attempts to diverge from the known information in order to generate unknown directions. The
progression of research questions posed in LAO and our emergent theoretical understanding of collaborative literacy were prompted by this continual, iterative, convergent–divergent process.

Important influences on the emergence, selection, and reconsideration of the theoretical components embodied in the design of LAO were the prioritizing and pruning of the many design ideas put forth by the team. Evident in any design activity, this reductionist task began with defining learning targets in the enactment phase and continued iteratively through the local evaluation phase as multiple design ideas were generated, then evaluated, and ultimately implemented, discarded, or adapted in some way. Decisions and judgments were made about the adequacy of design ideas in order to select particular aspects of a theory, design options, and research methods from the many possible alternatives at multiple points in the design path. Some simplification or reduction of information was necessary in the design because “. . . to deal realistically with the complexity and complication of large amounts of information, within a reasonable amount of time, it is necessary to find ways to simplify. This means ignoring or leaving out things that cannot easily be characterized” (Nelson & Stolterman, 2003: 187). Some theoretical constructs may be difficult to express in a design, so constructs that translate more easily to the classroom or technology environment may be more prevalent in design research. Because design is an interpretive act, theoretical constructs embedded in LAO were selected, reinterpreted, and refined continually as design ideas were generated, adapted, implemented, or discarded.

Conclusions

What is clear from investigating the act of design in design research is that the process is more complex than considered previously. By acknowledging the fluid, dynamic, evolving nature of design in design research, as well as the many layers of decisions and judgments required in design, we conclude that multiple factors may influence empirical and design decision making. These factors can include pragmatic, political, and applied methodological influences, among others, and provoke design researchers to consider other factors involved in design research beyond a sole focus on theoretical conjectures. Investigating the acts of design inherent in design research by analyzing the multiple cycles of problem states, decision–evaluation processes, and design moves can help to clarify and illuminate important decision making. Tracing this decision making in the LAO example revealed that the generation and refinement of theory and the selection of research questions, methods, and design features were intertwined inexorably with the more pragmatic processes of design.

There are many possible paths in design research, and knowledge of the design road taken as well as the one not taken can inform empirical decisions. Employing the lens of the design process can assist design researchers in generating and examining the progression of their decision making and judgments based on multiple factors and may shed light on important contextual issues that promote the selection of specific research questions and design features (O'Donnell, 2004). Acknowledging fully the act of design in design research may move us closer to articulating the processes and procedures explicitly and provide improved information on how researchers determine which aspects of theory, research questions, and design features to address in this complex endeavor.
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