Conjecture Mapping the Library: Iterative Refinements Toward Supporting Maker Learning Activities in Small Community Spaces

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Abstract: A recent and important innovation in design-based research (DBR) is the use of conjecture maps, where researchers explicitly articulate the conjectured mediational relations between their designed goals and the learning designs and contexts. In this paper, we present a design case as an iterative sequence of evolving conjecture maps. As each conjecture map was tested, we revised it to highlight and refine our articulation of the tools and processes that embodied our design approach. Our design case involves small-town and rural community and school libraries in the United States as partners and DBR sites, with the goal of supporting librarians as they learn to develop and enact new STEM-oriented maker programs for youth. We show how conjecture mapping informed and supported our DBR work and how it helped push for specificity in hypothesized relations between the design, the learning setting, the outcomes, while also forcing a reflection on design constraints.

Introduction

A hallmark of the Learning Sciences in the decades since its inception is design-based research (DBR) (DBRC, 2003). While the digital age portends the increased availability of new technologies to support learning, we contend that design-based research, with its focus on understanding and refining practical and theoretical knowledge about how change is effected in real world use contexts, remains both important and necessary to the Learning Sciences scholarly community. To that assertion, however, we note that efforts to critically reflect upon and modify the work and practices of DBR have been fairly limited. Relatively recently, there have been new proposals for modifying the stances and routines of DBR, such as social design experiments – where equity and issues of justice are top-level foci (Gutiérrez & Jurow, 2016), design-based implementation research – where large educational systems are enlisted as sites and partners for designs addressing problems of practice (Penuel et al., 2011), and conjecture mapping – where design researchers explicitly specify the conjectured mediational relations between their goals and the learning environment (Sandoval, 2014). The latter is the focus of this paper. In following with a more recent turn in DBR research toward presenting design cases and how they adapt over time (Svihla & Reeve, 2016), we present our design case for inspection.

Our design case involves small town and rural public and school libraries in the United States as partners and DBR sites. Recently, libraries have been generating interest in Learning Sciences as designed learning spaces (Lee et al., 2016; Subramanian et al., 2012). Successful implementation of new learning environments and programs within libraries have typically involved large libraries in urban communities, with the *YOUMedia* program in Chicago (Austin et al., 2011) and the Bubbler in Madison (Halverson et al., 2017) as noted examples in the United States. Less well represented in the Learning Sciences literature are libraries that serve small towns and rural communities. Libraries serving these communities offer unique challenges: their staffing levels tend to be lower, staff are less likely to hold appropriate library certification or degree, and resources are typically insufficient (Barron, 1995).

In this paper, we begin by describing the settings for our work, and our goal of supporting librarians as they learn to develop and enact new STEM-oriented maker programs for youth. We present this work as an evolving sequence of conjecture maps that articulate theoretically important features of our design and how they were expected to produce intended outcomes. As each conjecture map was tested, we revised it to highlight and refine our articulation of the sociotechnical tools and processes that embodied our design approach. In this way, we show how conjecture mapping reflected, informed, and supported our DBR work. In following with other published models in the Learning Sciences (e.g., Edelson, Gordin, & Pea, 1999), we identify how our understanding of a complex learning setting and leverage points developed over time. We also articulate what conjecture mapping offer to learning scientists over an extended period of design research.

Literature review

The origin of design-based research is often traced to the early 1990s and the writings of Ann Brown (1992) and Allan Collins (1992). While the terminology originally differed in those early works (i.e., design experiments and design science, respectively), the fundamental orientation remained the same: researchers aimed to establish

practical theory from creating, testing, and refining educational resources and learning designs in real world settings. The educational theory to be developed, termed by some as "humble theory" (Cobb et al., 2003), would knowingly differ from the kinds of grand theories associated with laboratory science which often attempted to uncover fundamental and unifying principles and laws that transcended contexts and setting. For education, which involved inherently complex relations and practices, an alternative research approach was needed that could support the discovery and realization of educational goals. As an example, design-based research could establish new kinds of scientific practices that could be realized in a K-12 classroom (e.g., argumentation) and articulate the means and tools necessary to get there.

Conjecture mapping (Sandoval, 2014) has been introduced as a means for such articulation. It arose from the observation that while there appeared to be uptake in the use of DBR (Anderson & Shattuck, 2012) and in its sanctioning within official publications (e.g., Sandoval & Bell, 2004), processes for doing DBR were ill-specified. At its core, conjecture mapping involves the following elements: 1) a *high level conjecture* about how to support learning, 2) the *embodiment* of that conjecture in a specific design, 3) *mediating processes* produced by the embodiment to yield 4) desired *outcomes*. The relationship between the embodiment of the design and the mediating processes are the *design conjectures*. The relationship between the mediating processes and the outcomes are the *theoretical conjectures*. Through conjecture mapping, the simultaneous work of developing a design to support learning and developing theory can both be brought to the fore. Sandoval (2014) represents these relations in a manner comparable to Figure 1.

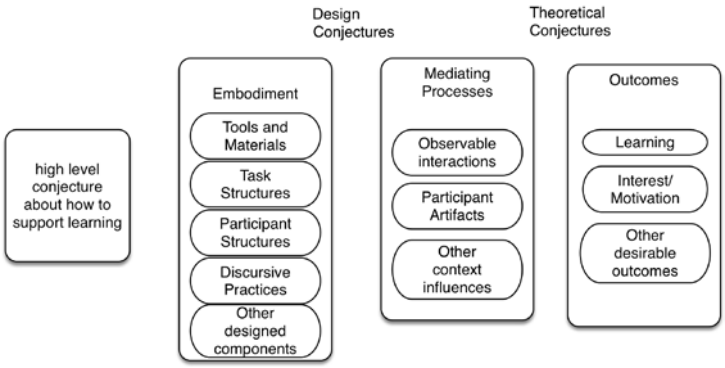

Figure 1. The grammar of conjecture mapping.

Informally, this grammar for describing design-based research has been enthusiastically received by the Learning Sciences community, but instances of it have rarely appeared in the literature (W. Sandoval, personal communication, May 12, 2017). Throughout this paper, we use the grammar and vocabulary of conjecture mapping to present the iterative (and still evolving) conjectures we have been developing to support the following initial high-level conjecture: *given appropriate supports, libraries is small and rural communities can provide a range of Maker and STEM-oriented educational programs for youth patrons that enable production of functional and digitally enhanced artifacts*. Similar to how others have used high level conjectures, ours includes a vision of learning and learning environments and how particular forms of it can and should take place in library settings. As will be seen below, this high level conjecture, the embodiment of design decisions, mediating processes, and outcomes have changed over time to help us better understand the domain and the supports necessary to engineer our intended learning activities.

Data sources

Partners for this design work include four middle school libraries from a single, rural-serving school district in the United States and two public libraries in small towns within the same school district boundary. Data have been collected at virtually all of the libraries and with all librarians at these sites, with three school libraries and one public library providing the bulk of our data (an intentional move as part of the larger multi-year research and design project). Data included 160 hours of observation documented with 183 pages of field notes and 191 photographs, six recorded interviews, two focus groups, notes from our design sessions, and other artifacts (e.g. librarian produced marketing, school district meeting minutes), collected over approximately 18 months.

By design, we emphasized an observational stance during the first phase of the project (roughly six months). That is, we limited any intentional introduction of new tools or resources and primarily conducted weekly observations and interviews with librarians and at our partner libraries to understand existing practice. This was in line with adoption of contextual inquiry (Beyer & Holtzblatt, 1998) as an overarching design

approach, where the central and primary commitment is understanding what individuals are doing within their existing spaces. In the second phase, we began to take our initial observations to develop prototype activities and resources that we then tested with librarians and youth patrons in focus groups and workshops, with the expectation that these would need substantial and continual revision. That phase has taken roughly a year of continuous work and just concluded prior to authoring this paper. A third phase is currently underway.

Data analysis

As a design-oriented paper, our goal is not to provide an extensive accounting of our analysis of all collected data. More traditional empirical studies are forthcoming. We do note, however, that our analysis activities have involved systematic coding of field notes and interviews using accepted methods associated with qualitative research (Saldaña, 2015) to inform our assertions. Given our goal of applying conjecture mapping and demonstrating how conjecture mapping can articulate changes in knowledge gained from design research, we present descriptive excerpts for illustration and justification rather than counted codes. Due to space limitations inherent in conference papers, we will only be reporting on some of our realizations and conjecture mapping.

Evolution of conjecture maps

The initial conjecture map

At the start of our design-based research project, we had a rudimentary mapping of how our design work would lead to a set of desired outcomes (see Figure 2). Namely, we collaborated with partnering library directors and school librarians who had expressed interest in having their libraries participate in the "Maker movement" that has been increasingly appearing in their professional literature (e.g., newsletters and journals) and communicated to them from various stakeholders or affiliates (e.g., district office coordinators for school libraries). The outcomes we hoped to realize were instantiations of high quality youth Maker programs created by our partner librarians and an increase in the amount of Maker programming. We knew that libraries, including those with whom we had partnered, already hosted youth programs and activities – whether it was gaming groups or afterschool homework clubs. This existing youth program development expertise was a key mediating process and a resource to enable the creation of Maker programs. As this was a new endeavor, we expected that our research team would have more direct involvement when we transitioned from observational to interventional work, with our university-based team members taking on more active development and facilitation roles for some Maker programs and helping to conceptualize program opportunities given our own extensive prior engagements with the larger Maker education research community.

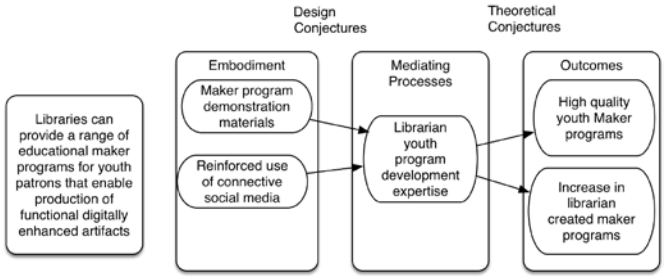

Figure 2. Initial conjecture map.

Our expectation was that after some initial time investment in working with and observing the libraries and their personnel, we would be able to create a set of demonstration materials that embodied realistic enactments of Maker programs in small libraries. We also had the expectation that there were a number of existing digital informational and communications resources through which libraries learned about possible program ideas, such as social media and email lists within the local professional community that would enable knowledge sharing of different kinds of library-based programs. We hoped to discover and enact means for building upon those connective media. For instance, we assumed that social media use kept libraries abreast of what other libraries in the region were doing and could be reinforced to promote, model, and share ideas for Maker programs.

Given our expectation of existing use of informational and communications media, particularly within social media among librarians, and an ease with youth program development, our data collection approach was to initially observe existing library program development practice without any researcher intervention. That is,

we shadowed librarians at work, interviewed and observed them as they came up with youth programs, and attended and observed those youth programs and other routine activities at our partner libraries.

Initial discoveries

From our early observations and interviews, we were quickly humbled as project partners. The number of responsibilities and expectations placed on library professionals, whether they worked in a school or public setting, were well beyond what we had anticipated. In hindsight, this was naiveté on our parts by not having previously researched how librarians work and learn. For example, within the school library setting, there were constant demands on librarian time, with librarians taking on instructional planning, student advising, class supervision, assessment, financial management, school technology support, and fundraising above and beyond collections development and management. Observational interviews with school librarians often took place while things were momentarily quiet and the librarian was answering our questions while simultaneously shelving, assisting students, or preparing the library for a class of students arriving during the next period.

In the public library setting, there were demands on staffing, grant writing, customer service, report preparation, and community relations. In addition to these activities, this meant that youth programs were considered in fleeting moments when they were not already obligated to another service. Very limited staffing meant that there was one full-time employee in the school libraries and usually just one at the public libraries, given their small size. In public libraries, when there was the luxury of more than one full-time staff member, the individual who coordinated and facilitated youth programming had several other responsibilities beyond that. This is in contrast to larger libraries that have a dedicated youth services librarian.

The need for "at-a-glance" program planning materials

When we observed and inquired about youth program planning, we saw that the librarians who were most directly involved would conduct quick online searches for program examples, with social curating sites such as Pinterest mentioned regularly. Often stated as driving program constraints were what librarians had heard about or knew youth would be interested in doing and what would be relatively quick to prepare and familiar enough that they could execute the program given limited preparation time and budgetary resources. As we probed what led librarians to proceed with program design in this way, we found that it was largely driven by a desire to find new ideas quickly, to "see things in pictures," and to adapt without extensive preparation on their part. For instance, one librarian relied on Pinterest for images of Harry Potter craft activities that could be adapted as a youth library program.

As we began some very early user tests of prototype demonstration materials with librarians in the form of print materials, images received the bulk of attention, large sections of text were ignored, and the librarians made active requests for more pictures of completed examples and how they worked. That led us to focus on highly pictorial materials and to explore strategies to represent completed examples and models in more immediate ways than what existing Maker education resources typically do. In this way, we discovered that the quick glance a librarian might take would reveal to them what could be possible and attainable.

Variable images for desirable librarianship practice

We also learned from our observational work that different librarians had very different images for what constituted a successful youth program. On the more conservative side, as conveyed by one of our partnering school librarians, an image of a program would involve youth quietly working on a creative activity that posed no disruptions to others who were visiting the library seeking a quiet reading or study space. Toward the other extreme, a public and a school librarian stated that libraries should be lively, noisy spaces during adolescent youth programs. We observed, and have noted elsewhere (Lee, Lewis, Searle, et al., 2017), that a librarian's sense of librarianship practice – including what youth behaviors should be like, what purposes youth programs served, and what should be expected during a youth program – strongly influenced how different forms of youth program were designed and enacted by different librarians. Those who saw their work as maintaining and reproducing services in a self-contained way tended to have rigid programs that were not well attended by youth. Those who saw their work as reinventing the library and connecting to whatever resources were available in their immediate community had highly attended programs and were described very positively by vocal patrons and community members.

Treatment of physical and occupied space in the library

Finally, we observed that at programs with high levels of youth participation, the youth acted in ways that suggested a very different relationship with the library space and place than would be seen in a more typical

classroom. Libraries that hosted highly attended youth programs had youth who spoke out without raising their hands, would take off their shoes and walk barefoot in the library aisles, would sit with their feet on tables or sit on tables themselves, and play loud music and dance. One public library hosted teen programs after regular library operating hours. Adult patrons were not allowed, furniture was freely rearranged, and teens ran, laid on the ground, texted friends or played board and phone games, or found private nooks to sit and congregate with friends. This suggested to us that how the library space was understood – in terms of who should have access and what behavioral norms were acceptable – were important for youth to be motivated to actively attend and engage. This was confirmed in interviews with librarians. These observations led to a major revision of our conjecture map, described in the next section, as we more actively began to develop and enact new programs.

The second conjecture map

As we transitioned to design and implementation of Maker activities and away from strict, non-interventionist observations, one major change to our conjecture map was a change in its high-level conjecture (see Figure 3). Whereas before our conjecture had been about enabling Maker programs to take place in the library generally, we came to recognize that our partner librarians felt limited in their prior knowledge related to Maker programs and limited in their time to learn what they believed was necessary to support Making. This tied into a perceived idea of who gets to be a Maker and what activities constitute Making. In light of that, we internally and externally adjusted our expectations that the Maker programs offered in these libraries would appropriately be presented as low threshold, entry-level activities. We did not expect that the librarians would establish and lead robotics and coding clubs, and recognized that they often preferred to bring in someone else from their community (e.g., another teacher in the school for a school library or a representative from a community organization) for activities that went beyond what they felt they could learn and lead in a short amount of scattered preparation time. While supporting that, we also wanted to empower the librarians to lead programs.

Beyond changes to our high level conjecture, the embodiments of our design activities changed dramatically from what we had originally anticipated. In light of how we observed librarians curating program ideas and what kinds of materials they felt comfortable using, we began to develop visual guide program materials that were intended to encapsulate information about how a library Maker program could be sequenced, what materials were needed, and some fundamentals necessary for the creation of workable digital artifacts. For instance, a simple template for creating a basic paper circuit was necessary to establish some basic rules for connecting components into a functional circuit. When we tested templates that were available freely online, we discovered where novice users made errors (such as in tearing copper tape to make corners or creating short circuits near batteries) and made our own version of simplified materials that avoided some of these challenges.

We then found was that once we created these visual guide program materials, some librarians thought they should also be given to their youth patrons. This meant that some youth received materials explaining how library activities should be sequenced, how to address learning goals, how to communicate with youth patrons. In light of that, we began to deliberately separate materials for the librarian to plan the program, and materials for the librarian to copy and share with youth. This combination of librarian materials and patron materials was intended to provide new images for what could be done within the library, how the space within the library could be used, and decentralize expertise so librarians did not feel that they must present themselves as experts.

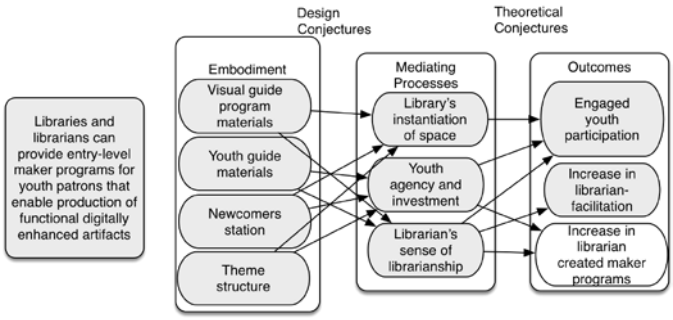

Figure 3. The second conjecture map, with major changes highlighted in gray.

During our first enactments of newly developed Maker programs in the libraries, we observed immediately that youth had variable attendance. When a series of programs was offered over multiple days, some youth would show up for the first time on the third day and others would show up only on the first and last days. As such, we observed it would be difficult to design sequences of activities that became more advanced

over time because invariably, new youth who had never attended would arrive. We began to explore clearly identified 'Newcomers stations' so that first time and 'drop-in' program attendees could get started on their own.

We also noticed that many youths who came complained that they did not know what to Make. After a few different attempts, and in consultation with participating youth, proposing a theme was recognized as an important program structuring element. For instance, if the theme was "Fun and Games", attending youth enjoyed displaying how they could creatively embody that theme in their creations and what they could create that might push the boundaries of "games" (e.g., such as Pokemon Go vs. a board game). Also, we had observed some libraries had multi-week themes, such as "Marvel" films, that librarians reported resulted in increased youth attendance at programs. Building on that seemed to attract youth, according to librarians, and showed the range of ideas youth had for what could be made (e.g., a superhero mask vs. a weapon vs. a film scene).

Our intended outcomes from this conjecture map modification and for the subsequent six months of design and implementation work were: to emulate engaged youth participation comparable to what librarians reported as taking place during their most successful youth programs, to ease the librarian into being a comfortable facilitator and helper for students rather than feeling the need to be a content expert, and to use the successes of these experiences to empower librarians to create their own Maker-themed programs. We next describe two observations from enactments of library programs.

Need for more initial investment from youth

The new conjectures we established seemed more appropriate and tractable. Evidence for this included our librarians taking on more assistive (rather than leader) roles with youth patrons during program enactments, as well as strong program attendance. Still, some Maker activities and technologies had a much more enthusiastic reception from youth than others, including ones that the librarians and we had thought would be positively received. We thus began to see the need to increase youth involvement in initial program conceptualization. At some public libraries, teen advisory boards exist to get feedback on program ideas. Their members seem to also show heavy investment in library-based programs and are key figures in publicizing the programs and bringing new youth to the library. The literature on teen advisory boards is sparse, but working with them directly was fruitful for our design work and also empowered librarians to feel more confident in their decision making. We have since been working with our school librarians to encourage them to establish their own teen advisory boards, which is not a typical structure in school libraries. In addition, we introduced practices of intergenerational co-design (Guha et al., 2013) into researcher-librarian-youth program conceptualization.

The 'domino effect' of participating in Making at the library

As noted above, one librarian was more conservative and structured and tried to keep everyone at the same pace. In these instances, youth guide materials were supportive of the librarian's preferred style of instruction. However, in more unstructured enactments, we saw librarians leave the youth guide materials out near the activity. Then, when these were used, one youth would figure out what to do, and then others would observe what that youth was doing and imitate him/her/them, and then occasionally expand on that in ways that would then be imitated by others in its new expanded form. In Maker learning activities, Blikstein (2013) noted a 'keychain' effect where youth would restrict themselves to making a single example when exposed to a new Maker technology, for example 3-D printing the same object (e.g., a keychain) repeatedly. In Blikstein's work, the 'keychain' effect was viewed critically, rather than as an opportunity for learning. However, in our context, a 'domino effect' took place where guide materials we had designed were initially used by one youth, and observation of what that youth was doing and then personal modification contributed to other youth subsequently engaging in the Making activity. When new youth joined, they ignored the guide materials and opted to learn by watching. This social process of observation, imitation, and modification as a kind of vicarious learning was not one we had expected, and is now one we wish to account for in the design of library-based Maker programs. This process does not eliminate the need for youth guide materials, but has introduced different patterns and evolutions in youth participation.

The current conjecture map

We have begun a third phase of work involving another design iteration with new librarians and new cohorts of youth. This has also entailed revisions in our conjecture map and our related design work (see Figure 4). First, the split between program materials and youth guide materials seemed consistent with what librarians wanted and used. However, we observed that for some librarians, the youth guide materials took primacy and the programs became exercises in students working through those only. We also observed the aforementioned 'domino effect' where youth guide materials were used once by one or a few youth to get the activity started and then ignored by others.

Additionally, drawing from Learning Sciences innovations where science curriculum materials were enhanced to become educative curriculum materials (Davis & Krajcik, 2005), we began to modify the librarian program materials to become *educative*. We have systematically reviewed recently identified design principles for educative curriculum materials (Davis et al., 2017) and identified translations for the library setting. We are adopting those principles for the library context and are examining how well our embodiment of those supports changes how librarians view, enact, and facilitate educational programs.

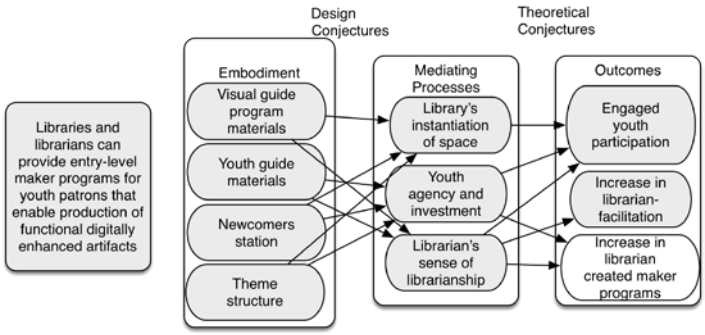

Figure 4. The current conjecture map with changes from previous iteration highlighted in gray.

With respect to outcomes, the 'domino effect' described above alters our expectations for librarian facilitation. In part, we have come to see that a librarian's sense of librarianship – including their view of how activities should be enacted in libraries and what role the librarian should play – still influences their facilitation. Changing the sense of librarianship is a long term endeavor, comparable to how teachers change their teaching practice. Still, we have observed modifications in the librarians, such as expanding the range of program offerings within library spaces and using teen advisory boards to help distribute expertise and support youth programs. Informally, we are seeing an increase in new library programs being initiated by our partner librarians using prior programs as inspiration. For example, we are seeing one partner school librarian encouraging the use of cardboard with students to engineer miniature skating parks and launching steampunk fashion making activities without our prompting and another has been making terrariums. As this next iteration of design and enactment of youth Maker programs in libraries unfolds, we will continue to examine if our conjectures are indeed plausible and attainable through our design work and revise and test more as necessary.

Conclusion

The goal of this paper has been to demonstrate and apply conjecture mapping grammar to iterative work with small town public and school libraries. We presented three iterations of our conjecture maps developed over 18 months of a design research partnership. In doing so, we note several things. First, while conjecture mapping pushes for specificity in hypothesized relations between the design, the learning setting, and the outcomes, the process of conjecture mapping also forces reflection on constraints. Many examples in Learning Sciences research that have reflected upon design have been in classroom settings. By moving to the library setting, a new set of constraints associated with the target population and demands on professionals working in this space have surfaced. The specific embodiments of design decisions were informed by these constraints, and the process of conjecture mapping prompted reflection on them. In conjecture mapping of new domains, we believe it is necessary and productive to identify and articulate constraints. That may not require additional components to a conjecture map diagram, but they are important parts of the design process.

Second, conjecture maps will undergo change over time, and design cases that make these changes visible will be instructive for the community. In our work, we have recognized where we were too general in our assumptions, such as what supports and exemplars would be adequate for use in library-based learning. Indeed, the need for more necessary supports in the process of iterative design has been documented elsewhere (Edelson et al., 1999). However, a push for final-form relations can mask the many decisions and influences involved in realizing an educational design. Like others (Svhila & Reeve, 2016), we believe that surfacing these helps the community appreciate and relate to the complexity of the work of doing design research.

Finally, conjecture maps push researchers toward articulating mediators within the system. For us, we have begun to articulate the kinds of entities and competencies that one ought to consider in our design space, such as how physical space is arranged or the sense of librarianship maintained by individual librarians. The precision required of conjecture maps encourages these articulations, and thus it seems to be a promising support for ontological innovations in design research (diSessa & Cobb, 2004).

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Acknowledgments

This work was supported by Institute of Museum and Library Services grant number RE-31-16-0013-16.