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Understanding and Representing Learning Activity to Support Design: A Contextual Design Example

Mark Notess
Digital Library Program
Indiana University

Music Library
1201 E. Third Street
Bloomington, Indiana USA 47405-7006
+1.812.856.0494
mnotess@indiana.edu

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Abstract

Contextual Design is a well-defined method for gathering and representing user understanding within a coherent design process. This paper illustrates the value of Contextual Design to educational system design by describing a case study involving 14 contextual inquiry sessions that were carried out in and around the Indiana University music library, in support of designing technology for student learning. Findings are presented as diagrammatic work models, an affinity diagram, and a list of insights and design ideas. The utility of Contextual Design work modeling is assessed, and some limitations in its ability to represent learning are considered.

Introduction

Designing useful educational technologies requires us to understand the potential users of those technologies, the tasks the users bring with them, and the contexts of use. As we have developed our next-generation digital music library, Variations2 (Variations2, 2005), we have taken a valuable opportunity to gain this understanding by studying usage of its predecessor, the Variations system (Dunn & Mayer, 1999; Variations, 2005). This paper reports on the second in a sequence of contextual inquiry studies of digital music library use. Results from the first study have been partially reported (Notess, 2004a). A small subset of results from the present study were reported elsewhere (Notess, 2004b).

Contextual inquiry (Holtzblatt & Jones, 1993) is a naturalistic inquiry research method wherein researchers observe actual work in normal work contexts. The method is intrusive in that the observer sits with the participant and asks clarifying questions during and/or following the session. An advantage of contextual inquiry over an interview or questionnaire protocol is that it gets beyond the participants' beliefs about their activity and records actual practice, which often differs from how participants believe they behave. Data from contextual inquiry has proven very useful in information systems design. Recently, it has been applied to the design of educational technologies as well.

Contextual Design (Beyer & Holtzblatt, 1998) extends contextual inquiry by situating contextual data within a coherent design process. Central to the design process are five types of diagrammatic "work models" which serve to represent, consolidate, and communicate the findings of contextual inquiry in a manner useful to technology design. This paper illustrates the application of Contextual Design (CD) to educational technology using a case study of digital music library use at Indiana University.

Motivating the study were the following research questions.

- What is the role of the Variations digital music library in the studies of music students? Into what larger patterns of student work does a digital music library fit?
- How do students decide between using online and physical resources? For online resources, what use do students make of the non-library web?

Beyond these primary questions, we were also interested in characterizing the suitability of contextual inquiry and the CD work models for examining and representing student library work. The CD models were developed primarily for describing business-oriented work activity. Whether the models adapt well to representing learning activity is an open question.

After describing the digital music library technologies and the method for conducting the observations, this paper provides examples of the five CD work models, describes the useful outcomes of the study for Variations2 design, and offers a preliminary assessment of the CD models' utility in studying learning.

Study Description

Variations and Variations2

Variations is a large digital music library implementation at Indiana University (IU), in use since 1996 to provide streaming audio and digitized score images to music students at computers in the music library. The

approximately 1500 School of Music students make frequent use of Variations for course reserves and personal study although anyone with an IU network login may go to the Cook Music Library and use Variations.

The collection includes over 10,000 digitized recordings. A Variations recording comprises a CD, CD set, LP, LP set, tape, etc.; hence, an item in the library catalog maps to a single Variations item. The Variations collection has grown through successive semesters of course listening reserves being requested by faculty. For copyright reasons, access to Variations is limited to PCs in the music library on the IU campus as well as to network ports in several music classrooms. Most usage of Variations occurs at the approximately 90 PCs in the music library. Recordings in Variations are accessed via a URL-based mechanism. URLs for Variations recordings are embedded in the online library catalog (IUCAT) records, but URLs are also available on HTML-based course reserve pages and can be put in any web page or typed directly into a web browser. Clicking on a Variations link or entering the URL in a browser brings up a web page summarizing the item and its contents. The Variations audio player is invoked by clicking on the a link to the desired side (or CD) listed on the web page. Since Variations recording files are stored on tape and copied to disk-based cache on demand, a user may have to wait several minutes for the player to appear if no one has requested that item during the previous day or two.

Variations2 is a completely new digital music library project that is replacing Variations at IU (the actual replacement occurred in May, 2005, subsequent to the present research). In addition to library functionality (resource discovery and access), Variations2 also provides pedagogical tools to support, for example, bookmarking, playlists, analytical and annotation tools, and listening drills. The research reported in this paper was carried out in support of designing Variations2 product features by better understanding how students work within the existing Variations tool ecology.

Participants

Our first study of Variations users had focused on undergraduate instrumental performance majors. For this study, we recruited four participants who were graduate voice students in a song literature class. We knew voice students had some needs we had not previously explored, such as viewing song texts, opera librettos, and their translations. Participants were selected from among volunteers signing up during a class presentation about Variations2. The selected participants, three males and one female, were the first four to reply to a follow-up email. Participants received a gift certificate in exchange for letting us observe and discuss approximately four to five hours of their academic activities.

Method

Observations occurred in sessions of between one and two hours in length. While we were primarily interested in their library work, we also wanted to get a broader picture of voice students' information needs in their academic activities. Therefore, we included observations of other activities such as voice lessons (both teaching and taking), class attendance, and ensemble rehearsal. In some cases, depending on the nature of the work being observed, it was possible to discuss aspects of the activity during the observation. For instance, during library stack browsing, it was easy to talk about what the student was looking for and why. During less interruptible activities such as taking a class or giving a voice lesson, the observer saved up questions and clarifications for a subsequent discussion with the participant.

Participants were requested to do their normal academic activities (whatever they needed to do next) and were observed in their usual contexts—library computer carrel or work table, classroom, or lesson studio. Data were collected with handwritten notes. No audio or video recordings were made. Artifacts, such as assignment sheets or student notes, were photocopied and annotated. At end of each observation, we talked with the participant to make sure we were understanding the observed activity correctly, to make any needed photocopies, and to set up any subsequent observation.

Contextual inquiry focuses on understanding the work being done, in all its richness. To collect these data, we ask questions to be sure we understand the triggers that initiate a work sequence, the intent to be fulfilled by the work sequence, the steps involved, the artifacts created or used during the work, the people communicated with, the pressures and influences that impact the work, the breakdowns that interfere with the work, and the environment within which the work occurs (Beyer & Holtzblatt, 1998).

Data from these sessions were represented in each of the five Contextual Design work models: Sequence, Flow, Culture, Physical and Artifact. Each type of model was then consolidated across the inquiry sessions to yield a consolidated model. Consolidated models indicate larger patterns without losing the detail of individual variation. Contextual design also includes an affinity diagram process, where researchers and volunteers create an extensive

affinity diagram of “work notes”, which can include nuggets of data from the models as well as data that did not fit neatly into any of the models.

Findings

We conducted fourteen contextual inquiry sessions. For all of these sessions, our focus was on the information needs of the participants. Ten of these were observations of library work; the other sessions included a voice lesson for the participant, a voice lesson given by the participant to a non-major (called a “secondary voice lesson”), a class session, and an ensemble rehearsal. All sessions produced at least some useful data with the exception of the ensemble rehearsal. This rehearsal was a dress rehearsal for a ballet that included choral accompaniment, but the focus of the rehearsal had nearly nothing to do with the singers, who were merely commended for their excellent work.

The ten library sessions included observations of the following kinds of work:

- *Listening assignment*. Students listen to an assigned set of songs, or select from among assigned songs, and write brief analyses of what they hear and think.
- *Recital assignment*. Students plan an imaginary voice recital following one or more specific themes, such as British art songs related by some thread such as having the same poet or same subject matter.
- *Audition “package” preparation.* Students auditioning for a summer singing job or other opportunity select vocal material to polish that will meet usual audition criteria for quantity and variety while also showing off the strengths of their individual voices.
- *Lesson piece, recital or performance part preparation.* Students study a particular piece or part for performance in their lesson, recital or a production. Study includes not only listening to and/or watching various performances but also uncovering background information about the composer, the poet, the performers, and so on. Study may also include making a literal translation of the text.
- *Song analysis project.* Students perform an in-depth analysis of a particular song, tracing its history through various performers and performances.
- *Exam preparation.* Students study a body of work so that they can identify and discuss a given song upon hearing it in an exam.

Work Models

Models included in this paper are consolidated work models (Beyer & Holtzblatt, p. 23): they represent multiple observations of similar work. In Contextual Design, consolidated models are built by induction from examining individual work models (models representing a single observation).

Sequence Model. Nearly all the library work consolidated into one of the two sequences shown in Table 1. The two sequences share some steps (“intents” in CD terminology). The key difference between the two types of work was twofold: whether the materials were pre-identified, and the level at which the studying occurred. For the “Study in Detail” sequence, the library material to be used was known ahead of time, or was selected from a predetermined list, and just had to be located. For the “Collect and Select” sequence, the student started with criteria but not material. Finding material that met the criteria, through a process of building a candidate pool and then selecting from that pool, was part of the work itself. Materials were selected based on descriptive data (length, language, key, etc.) and a more cursory listen to the content than in the first sequence. In the first sequence, detailed, repeated listening to the content absorbed the attention and the descriptive data were used more sparingly (performer name was the most common).

Although our data did not show these two sequences in combination, it was clear that some tasks begin as “Collect and Select” but will later require “Study in Detail.” The song analysis project, mentioned above, is one example: one first has to select seminal performances of a piece and then listen in detail to complete the musicological analysis.

The sequence model has an additional level of detail not shown here because of space limitations. The lowest level of detail, “abstract steps”, describes the steps taken to accomplish the higher-level intent in the table. For instance, in the “Study in Detail” sequence, the “retrieve known recording” intent has the abstract steps shown in Table 2. Note: In Table 2 and elsewhere in this paper, the “BD”-prefixed comments refer to work breakdowns—observed difficulties.

Table 1. The Two Common Sequences of Library Work

Activity	"Study in Detail"	"Collect and Select"
Prepare to do library work	• get headphones • find available carrel • locate assignment • log in and locate on-line tools	
	• select piece to study • retrieve known recording • retrieve known auxiliary materials (scores, texts, reference works)	
Work with library materials	• study material (listen, and follow along in score and/or text; repeat whole piece or key parts) • make personal notes to capture key points gleaned from studying	• find candidate materials • examine many details quickly to decide which to select (listen, check length, performer, key, etc.) • make personal notes to guide selection
	• write assignment deliverable	
Wrap-up the work	• preserve notes and/or assignment deliverable (email to self, save on Zip disk or network drive, print) • log out • pack up • return reserve materials • return headphones	

Table 2. Abstract Steps for "Retrieve Known Recording"

• Find course reserve list • Scroll to desired recording (BD: reserve list may be very long) • Select item (BD: easy to pick wrong item due to title similarities) (or) • Looking at assignment sheet, type Variations URL for item in browser field (or) • Enter search terms in online catalog • Scroll through search results to find desired item (BD: easy to pick wrong item due to title similarities and lack of distinct visited-link color) • Select item
• Select CD/Side within Variations web page

Culture Model. The consolidated culture model, which captures the power, influence, and emotional dynamics between people and groups, is shown in Figure 1. This is not a particularly rich example of a culture model. The relative paucity of culture data likely results from the fact that the work observed was primarily individual study within a well-defined hierarchy (teacher-student). If our observations had focused on collaborative or competitive activities, more cultural forces would probably have emerged.

Of potential interest from this diagram is the one breakdown, shown in the diagram with a heavy zigzag. None of the participants was willing to recall material on loan to another patron. In one case, the participant justified his reluctance by saying that if someone else had it checked out, he/she probably has a greater need for it. This situation illustrates an important limitation of physical materials and also shows that at least some parts of the community of music library patrons view their use of scarce materials as a collaboration rather than competition.

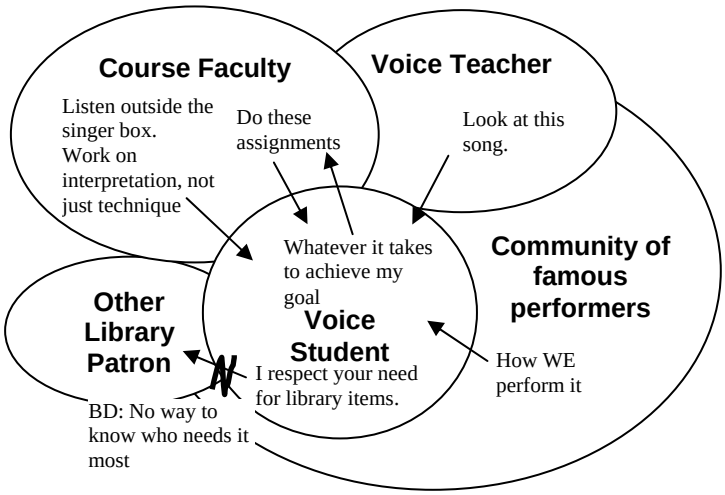

Figure 1. Consolidated Culture Model

Flow Model. The flow model (Figure 2) represents the movement of artifacts and communication between people (or roles) to accomplish work. Beneath each role are listed the observed responsibilities of that role. The arc labels in boxes represent tangible or virtual artifacts; the other arc labels indicate communication not formalized in an artifact.

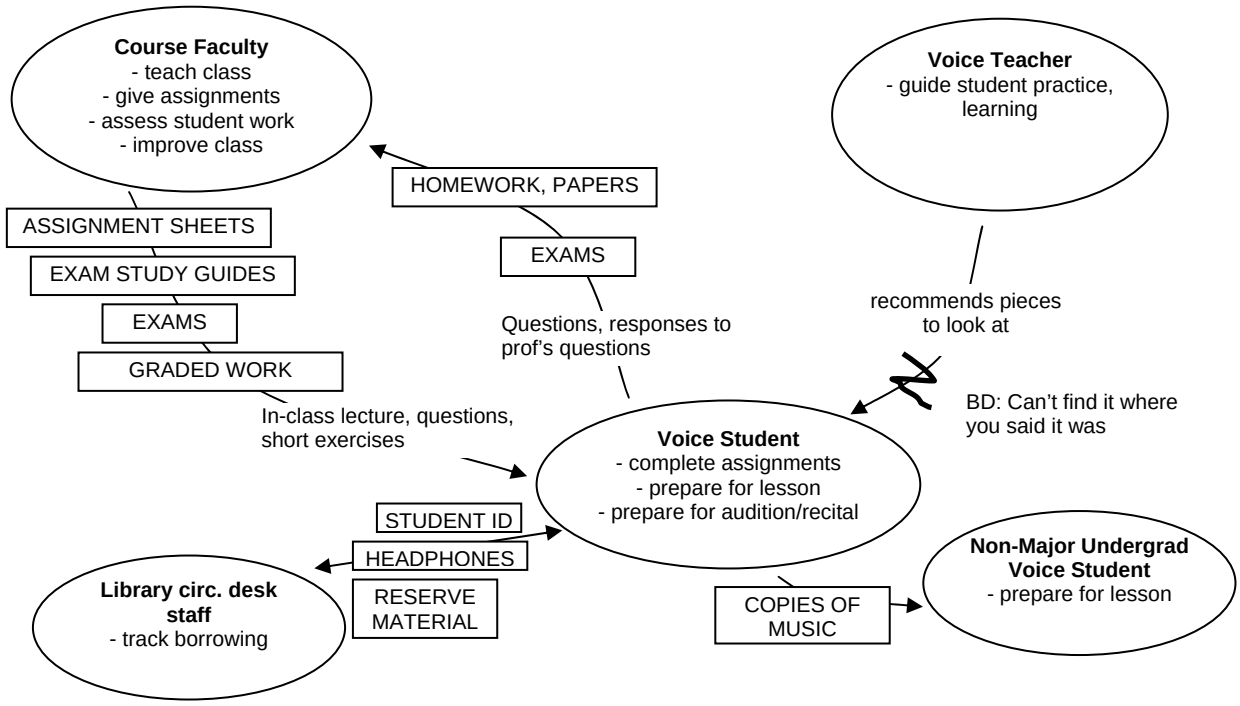

Figure 2. Consolidated Flow Model

As with the culture model, this flow model's relatively simplicity is due to the solitary nature of the observed activity. And again, it is the breakdown that is most interesting. In this case, we see that material known (or assumed) by one person may be unfindable by another. Two causes of this breakdown were observed. First, material may not be readily searchable using the terms in which people remember and describe it—looking for a particular singer may not work if works are cataloged using the name of the singer's ensemble rather than the individual performer. Second, it can be difficult to remember where materials reside—are they in the library or not?

Physical Models. A variety of consolidated physical models are possible, such as the arrangement of windows on a computer display, the library layout, or personal workspace. We show just one of these. Figure 3, the workspace, is illustrated with an annotated, mocked-up photograph taken in the actual carrels used by students. Usage of the workspace by students is remarkably uniform: students hold the auxiliary material (score, texts) in front of them, type with their arms lying across it, have a pile of other papers on their left (the right is kept clear for the mouse and the headphones cord) and use the shelves in front of them for other materials such as reference books. Backpacks are usually on the floor to the left of the chair. The carrels are uniformly sized, with no collaborative spaces available.

[image 1 goes here]

Figure 3. Physical Model: Library Computer Carrel

We noted several breakdowns in the physical environment:

- Headphones and headphone jacks sometimes do not work well. The ¼ inch jacks require students with their own headphones to buy and (more difficult) not lose a plug adapter.
- Sound quality is very important to voice students. They are also sensitive to background noise and to the sound leak from the open-ear headphones loaned by the library.
- The carrels, although capacious by some standards, are cramped work areas.
- During busy periods, students have to wait in line for a computer.

Artifact Models. In fact, multiple artifact models are needed: assignment sheets, completed assignments, graded assignments—these are the main artifacts. Space limitations preclude showing artifact models. The main breakdown associated with artifacts is that assignments were all paper-based. This introduced two difficulties: if a student forgets the assignment sheet, there is no way to retrieve it on line; second, long URLs and other text have to be retyped, sometimes introducing errors. The limited bibliographic data associated with Variations can be included in student deliverables via cut-and-paste, but the content (the recording) cannot easily be excerpted and used outside its context.

Other Contextual Design Outputs

Affinity Diagram. The CD process encourages capturing many "work notes" during modeling which are later turned into an affinity diagram. The affinity diagram is hierarchical, with the categories emerging from the low-level data. Starting with 138 total work notes, we ended up with five broad categories and one level of subcategories (Table 3).

Work note affinity diagrams are approximate, but they provide a fairly quick way of organizing a lot of information that does not always fit neatly into the more painstakingly constructed work models. Strangers to the project can use the affinity as an easy way to begin learning about at least one category of our users.

Insights and Design Ideas. The purpose of collecting and analyzing this mass of data is to arrive at useful insights into users, tasks, and contexts. Those insights in turn generate design ideas. Table 4 shows a sampling of the insights we gained. As the data reported in this paper are of necessity partial, some of the insights are from data or discussions not reported here. However, it is useful to show the full range of insights obtained.

Table 3. Top Two Levels of Affinity Diagram

1. The context I work in
   a. I have to work in a campus computer lab
   b. I have to learn the library
   c. Why I like Variations
   d. Problems I have with Variations
   e. I have to deal with my workspace
   f. How I manage my windows
   g. I have to manage lots of stuff
   h. I copy what I need
2. How I find
   a. How I find my tools
   b. I need the right song
   c. Search tools are clumsy and unforgiving
   d. I have to sift through results
   e. I try to find materials by browsing
   f. I use the web to find
3. Physical vs. Online Materials
   a. Why I won't/don't use physical materials
   b. Why I use physical materials
4. How I examine
   a. I need song length
   b. I have to assimilate lots of details
   c. How I decide what to sing
   d. How I prepare a song
5. What I have to do "for a piece of paper" [degree]
   a. [no subcategories]

Table 4. Insights and Design Ideas

Insight	Design Ideas
It takes too long to find offline materials for short assignments. (This is perception…is it true?)	Locate computer carrels close to physical material, or push wireless and put tables near high-use materials.
Finding things serendipitously (by online browsing or shelf browsing—not equivalent) is important.	Provide a way to browse, not just search, the Variations2 collection.
The value of peripheral learning is not always realized by students.	
Public computers in library treat all users as first time users, offering them the same configuration choices, etc., each time they sit at a different machine. This is inefficient but accepted.	[This is well beyond our scope but can feed into design of future computer labs in the library.]
Web resources are very important, especially Google and recmusic.org.	Provide links within Variations2 bibliographic data to good external resources.
To plan recitals, users may want to listen to several recordings in order, either from same or different CDs.	Define comparison sets or collections. provide a way to define a list of songs/pieces from same or different containers, and listen to them in order.
Students sometimes need to retrieve all performances of a given piece.	Allow search results to list instantiations (performances) by a performer, sorted by date.
Singers do many library tasks in parallel—they might be listening, following along in score or text, taking notes, polishing a deliverable, and/or searching/browsing for additional information or new material.	Variations2 should support parallel, not just linear, activity. Is a specialized window organizer needed?
Students can copy and reuse Variations bibliographic, but the collection content (the recordings) are not readily reusable.	Bring up just one song, not the whole container. Provide a way to build and share personal collections of excerpts. Variations2 bookmarking moves in this direction but does not allow excerpt specification.
The composer's key isn't necessarily the singer's key.	For vocal works, indicate what keys work for different voice ranges.

On the Variations2 development team, we have responded to the data in different ways depending on the nature of the finding. For example, after several observations demonstrated how important and challenging it was for participants to figure out song length, we immediately and easily added track length to the end of the track title in the Variations2 player. However, some ideas offer more fundamental challenges. Providing a way to retrieve all performances of a piece by date requires a substantial rethinking of the Variations2 search interface. It is not a quick

fix, so it will be considered as a requirement for a future release. Similarly, including data on what keys work for different vocal ranges would require additions to our data model, changes to which ripple through several parts of the system.

It is the nature of contextual inquiry to generate data on a broad range of concerns, often much broader than we expect when we begin the study. We come up with ideas for new tools or new ways to organize the library's physical space. We pass the data and ideas along to other people who have an interest in the problems raised—library administration or faculty.

Conclusions

Where Variations "Fits"

Initially, we asked how Variations fits into the larger patterns of student library work. An examination of each consolidated model reveals the various dimensions of "fit."

Sequence. Variations is the tool of choice for "listening in detail" or doing the overview listening needed for the "collect and select" sequence. Variations is also useful for comparing performances and determining a piece's length.

Culture. Variations allows students to learn from the "community of famous performers" more extensively and efficiently than they would likely do if they had to use physical materials. But because the Variations collection is not comprehensive, the "community" may be artificially limited based on what faculty have chosen to place on reserve.

Flow. Recordings are put in Variations at faculty request and serve as reserve lists for classes. As a result, class assignments depend on Variations, often identifying specific recordings by their Variations URLs. Yet whenever possible, students also rely on Variations for assignments that do not identify recordings. Attempts to direct students to Variations material without providing a link or URL are potentially problematic.

Physical. Students can only use Variations at public computers in the music library. Thus they must deal with issues related to public access computer stations: availability, configuration, maintenance, limited work area, etc. Because Variations is a Windows-based application with a one-recording, one window model, and because students retrieve information from many online sources and use word processing tools, Variations lives on a complex, crowded desktop.

Artifact. Students often access Variations starting from paper. Only the (limited) Variations bibliographic data can be included in student deliverables, not the music itself. The content is "locked" in Variations; hence students must describe the content themselves but cannot illustrate their description with excerpts. Content cannot be collected easily and set aside for later use—it must be retrieved again.

Thus it has been possible to determine where Variations fits by looking at the broader context. Contextual inquiry forces us to lift our gaze beyond our small piece of software and grapple with its place in a user's full experience. While detailed analyses of software can uncover ease-of-use problems (cf. Blandford & Stelmaszewska, 2002), such analytical approaches cannot tell us much about usefulness.

Physical vs. Online Materials

Deciding When to Use Which. For recordings, online was the obvious choice and overwhelming preference. Participants exhibited visible dismay when the recording they were interested in wasn't available in Variations. The common explanation for this preference was the convenience and speed of online access. Participants were unwilling to request physical recordings for short assignments. For larger assignments, participants indicated plans to request recordings from the library or borrow recordings from other sources (dormitory CD libraries, friends with large CD collections). One participant spoke of plans to burn needed songs onto a personal CD using the library's CDs and music software. Apart from CDs, students may be losing familiarity with recording formats. One participant found a 78 RPM item in the catalog but was not familiar with that format.

For visual materials such as scores, song texts or librettos, or reference works, preferences were less clear. Online scores are still not common. The only observed computer-based score usage was from a participant's personally purchased copy of a commercial CD containing a score collection. Participants expected to have to find physical scores via the library catalog or shelf browsing.

On the other hand, song texts and librettos were regularly retrieved online. Participants used copy/paste to put a song text into a deliverable or to prepare to do a translation. In one case, finding an aria in a book was difficult because it was not indexed. Numerous resources are only available in books; participants were comfortable finding

and using these—for longer assignments. For reference materials that were both online and on the shelf, preference seemed driven by familiarity and ease of access. One participant used the hardcopy *New Grove* dictionaries because he knew where they were; he didn't know how to access them online.

A lingering question is whether physical materials are as inefficient to retrieve as participants believe. Searching for online materials is not always fast or fruitful. With Variations, there is the potential for a several minute wait for the item to be copied to disk cache. An alternate hypothesis is that students don't want to get up and walk around the library more than they have to. Library carrels are a sometimes scarce and never secure workplace; it may well be that students are concerned about the security of their personal belongings and also do not want to "squander" a scarce resource—taking up a computer carrel but not sitting there. Another hypothesis is that online access "feels" more efficient even when it isn't.

Non-Library Online Materials Usage. Participants used non-library web resources extensively. For voice students, recmusic.org is well-known and heavily used. It contains a very extensive collection of art song texts and translations, and it can be searched and is indexed by title, composer, first line, language, poet, etc. Other web-based frequently used resources were Google, aria-database.com, and various commercial sites selling sheet music or scores.

Assessing Contextual Design Work Modeling

For solitary library-based learning activity, it is unsurprising that the culture and flow models are relatively sparse. Yet all model types have provided some amount of insight and provoked thinking about issues that might not otherwise have emerged from unstructured data. For example, participants did not mention feeling limited by not being able to excerpt Variations recordings, build a personal collection of them, or share them with others. This insight emerged from our design thinking based on the artifact model: creating artifacts is a process of taking raw material and turning it into something changed or new.

Some data of interest do not seem easy to capture in the existing work models and suggest the need to extend or adapt the models. The sequence model does not have a straightforward way of indicating the optionality of intents, or of showing the constraints that may determine whether a step is needed or not. For instance, if listening is for personal study and not a class assignment, some steps disappear (locate assignment, write assignment deliverable). While this can be modeled as two distinct sequences with separate triggering events, it would be more efficient to introduce a mechanism for indicating optionality based on constraints or personal preference.

The flow model describes how artifacts and communication move between people to accomplish work. But how does the work of individual learning occur? None of the models represents how learning occurs when students interact with library material. Insight into student learning likely requires a more detailed contextual inquiry than we conducted, examining student verbal reports of decisions and other thought processes. Yet had we gathered all that information—and we did gather some in the form of participants' notes and assignments—it is not clear where in these models we would represent such events as the dialog of students with their materials, the acquisition of skill, or the adopting of a perspective or cognitive framework. To represent learning, we likely need additional models whose constructs are grounded primarily in learning theory rather than in office-based work practice.

Future Work

This study produced a rich set of findings about where the existing Variations tool fit with student learning activities. It also yielded insights into how students decide between using online materials or physical materials. Finally, this example also suggested ways the Contextual Design models, developed in the context of information systems design, may need improvements to address the needs of learning technology design more effectively.

We plan to continue contextual inquiry into digital music library use, especially now that Variations2 has replaced Variations. We will continue to expand the variety of users and usages we study. Variations2 includes its own search interface as well as presentation of digitized scores, giving us new opportunities to explore the decision between using physical or online materials.

We also plan to explore methods compatible with the CD modeling approach that can capture data about how learning happens as students use digital libraries.

Contextual inquiry requires training and practice, is labor-intensive, and generates large amounts of data to interpret, model, and store. For researchers to be willing to use this method, they will have to be convinced of its value. A potential, largely unexplored value proposition is that CD models may permit meaningful, efficient comparisons between projects, enabling a core set of knowledge to be established. Having a core set of consolidated

work models describing sets of teaching and learning activities might be quite valuable for instructional technology designers.

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[Image 1, for figure 3]