Design Research For Personal Information Management Systems To Support Undergraduate Students

Abe J. Crystal

A dissertation submitted to the faculty of the University of North Carolina at Chapel Hill in partial fulfillment of the requirements for the degree of Doctor of Philosophy in the School of Information and Library Science.

Chapel Hill
2008

Approved by:
Dr. Jane Greenberg
Dr. Gary Marchionini
Dr. Paul Solomon
Dr. Deborah Barreau
Dr. Jim Gemmell

Abstract

ABE CRYSTAL: Design Research For Personal Information Management Systems To Support Undergraduate Students
(Under the direction of Jane Greenberg)

This dissertation investigated the personal information management (PIM) behaviors and practices of undergraduate college students during a four month academic semester period. Qualitative data on the day-to-day PIM practices for 15 students enrolled in an honors biology class were collected through in-depth observations and interviews. Four students experimented with MyLifeBits—a next-generation PIM system developed at Microsoft Research. A participatory design session involving six students explored and identified new directions for PIM design. Analysis of the field data revealed that students engage regularly in project management activities, and their work is often highly collaborative. Students were observed to have difficulty with core PIM activities, such as managing tasks and reminders (and both PIM and technical skills vary widely among students). Students were observed to manage a diverse array of information formats, applications, and media, which are rarely integrated. Gaps in understanding and awareness among students and instructors were also noted.

MyLifeBits was found to be intuitive and effective for visual browsing and refinding, although specific elements of the MyLifeBits user interface could likely be improved to support efficient task completion. The MyLifeBits system includes annotation, collection building, and other features that may support new approaches for making order and stimulating reflection. Observations of student usage suggested further design modifications to improve these features and supporting user interfaces.

Implications for future research and design include: Incorporating social awareness and communication into PIM systems to help reduce gaps in understanding and facilitate reflection; integrating collaboration technologies into PIM systems to support students' highly collaborative work practices; providing tools to stimulate reflection (e.g., personal analytics) and create reflective artifacts (e.g., journals, multimedia scrapbooks); shifting the focus of design to outcomes (such as, "getting my assignment done on time, and in the way the teacher expects") that PIM supports rather than the PIM process itself; and developing ways to scaffold students' learning of PIM skills, such as metadata creation, project analysis and management, collaboration, and reflection.

Acknowledgments

Thank you:

Jane, for bringing the energy, enthusiasm, relationships, neuroticism, and Jewish mom-style guilt needed to push through the seemingly endless dissertation process.

Gary, for patient support, always asking the tough questions, and letting me stay in his hotel room at CHI.

Paul, for putting up with my scattered approach to qualitative research.

Deb, for being perennially available as a voice of calm encouragement.

Jim, for supporting our project, MyLifeBits tech support, and always being interested in what I had to say.

Sri, for inspiring me to follow my passions, and a lot of beers.

Jean, for enthusiastically supporting my research even though it had little direct benefit to her or her class; and all the student participants, for helping me with my study, and not treating me like a total geek.

The SILS staff, especially Lara, for handling my always-evolving schedule and funding situation smoothly and with a sense of humor.

The SILS doctoral student community, for providing a sense that I wasn't totally isolated. Thanks especially to Jed, Lori, and Yan for providing feedback on my data analysis and themes.

Kathleen, for your love and support during a long journey.

My family, for helping me take every step along the way to where I am today.

You all made this crazy endeavor possible.

Table of Contents

List of Tables

List of Figures

Chapter 1: Introduction

1.1 Overview and objectives

This dissertation seeks to understand the personal information management (PIM) needs and practices of undergraduate students. The purpose of studying these needs and practices is to enable the design of PIM systems that can improve the educational experience of students. My goal is to enable the design of systems that not only support efficient access to personal information, but enable students to reflect on what they have learned, build useful portfolios of their work, and develop their metacognitive abilities.

1.2 Conceptual framework

This dissertation presents a conceptual framework based on a systematic review of the PIM research knowledge base. The framework synthesizes previous research (on PIM practices and behaviors, contextual metadata, PIM and capture system technology, and HCI in for PIM systems) to identify open issues for research and design. The framework is focused on four main PIM tasks: *refinding*, *reminding and task management*, *making order*, and *reflection and metacognition* (see Table 1).

Table 1. Users' tasks in PIM.

PIM There are four main tasks that PIM can support. I have derived these tasks from previous research on PIM practices (Barreau & Nardi, 1995; Capra, 2006; Kirsh, 2005; Marshall, 1998). See section 2.1, "PIM behaviors and practices," for detailed discussion of these tasks and supporting references).
Refinding. Accessing information that one has acquired and stored in a PIM system (such as an email to a colleague, a report downloaded from a Web site, or a picture from a friend's wedding).
Reminding and task management. Keeping track of what projects and tasks one needs to work on, including key deadlines.
Making order. Filing or organizing as practices that help make sense of a complex stream of incoming data.
Reflection and metacognition. Improving metacognition, the "activities and skills related to planning, monitoring, evaluating, and repairing performance" (Kirsh, 2005, p. 148), p.148. Reflecting on one's activities to understand them more deeply, and construct personal narratives.

In addition, the framework summarizes methodological concerns in qualitative field research and explores how this type of research can be fruitfully applied to the research questions guiding this study. I take a user-centered perspective (Boardman, 2004; Ravasio, Schär, & Krueger, 2004), which entails:

- understanding students' behaviors and needs
- identifying students' tasks and constructing realistic scenarios to represent them
- evaluating systems and interfaces based on how they support the scenarios and students' behaviors

The conceptual framework explores five major areas. Here is a brief synopsis of these areas:

1. *PIM behaviors and practices*

   This section covers definitions of PIM, and empirical research on how people "do" PIM in practice, using both analog and digital tools. Four key tasks are identified as components of PIM: refinding, reminding and task management, order-making, and reflection and metacognition.

2. *PIM and capture systems technology*

   This section covers the technical infrastructure available to support PIM tasks, including capture, indexing, semantic association, sensing, and storage.

3. *Contextual metadata in PIM*

   This section covers definitions of context relevant to PIM, and how context can be represented using metadata.

4. *HCI support for PIM*

   This section addresses the interaction styles and interfaces that have been developed to support PIM tasks.

5. *Qualitative field methods for studying PIM*

   This section discusses methodological issues in studying PIM practices and system use in real environments so as to inform system design (i.e., a "design research" perspective).

These areas are discussed in detail in each of the five sections.

My dissertation research is informed by four major conclusions drawn from the review of PIM research:

1. Research on people's PIM practices shows that individuals want to understand and use their information within a personal collection (i.e., an information/task space) that makes sense to them, while minimizing the cognitive and metacognitive costs of filing, retrieving, and using information (Jones & Bruce, 2005). However, this research is limited by a focus on small groups of technical users, and many studies are somewhat dated (Capra, 2006). In addition, researchers have often focused narrowly on organization and retrieval, neglecting broader problems (Boardman, 2004; Capra, 2006).
2. There has been extensive work on HCI support for refinding and reminding, but much less consideration given to making order and supporting reflection and metacognition (Bellotti et al., 2004; Bellotti, Ducheneaut, Howard, & Smith, 2003; Kaptelinin, 2003). Innovative designs have been proposed in each area, but only rarely have these designs been carefully evaluated in a realistic use context (Cutrell,

Dumais, & Teevan, 2006; Jones & Bruce, 2005; Jones, Munat, Bruce, & Foxley, 2005). In addition, the various types of support for these different classes of PIM tasks have not been fully integrated (Cutrell, Dumais et al., 2006).

3. There is a broad range of technical capabilities—including capture, indexing, semantic association and layering, and context sensing—available to support PIM and CARPE functionality (Czerwinski et al., 2006; Gemmell, Bell, & Lueder, 2006). In general, it appears that performance limitations are no longer the primary constraint on PIM system development.

4. There is a need for more detailed examination of PIM-specific metadata (Cutrell, Dumais et al., 2006; Jones & Bruce, 2005; Jones, Munat et al., 2005). While the design of this metadata can be informed by previous research on relevance criteria and context, there is a lack of research that specifically evaluates metadata in PIM (Cutrell, Dumais et al., 2006).

The conceptual framework (see Chapter 2) explores these issues in more detail. The research, described in Chapters 3 (Methods), 4 (Research Context), and 5 (Discussion), is designed to contribute to the PIM field by focusing on the gaps and opportunities summarized above.

1.3 Research perspective

This dissertation takes a *design research* perspective. Design research emphasizes the importance of understanding user needs through user research. User research seeks to understand behavior, particularly through fieldwork, in order to support design. The findings from user research can then support an iterative design process, in which design concepts and prototypes are created, and then evaluated by both designers and representative users. The evaluation identifies problems with and opportunities for improving the design. Ultimately, designs are refined into forms (artifacts) ready to be regularly used, such as a deployed research prototype, or a commercial or open-source product. As people use the artifacts, further opportunities for design and research become apparent.

The design research approach informed two components of this research. The first component is *ethnographic fieldwork*, in which students' PIM *practices and behaviors* were investigated through intensive participant observation and interviewing. The second component is a *technology probe*, in which students' use of current PIM technologies was examined.

This approach is consistent with current needs for research on PIM behaviors and practices. As Boardman (2004) has noted, the PIM field has seen extensive design and prototyping work, but little user research and evaluation. Thus, "many of the PIM prototypes… are not grounded in a firm understanding of user problems" (p.49). There is a fundamental "break in the task/artefact cycle. Studies of user practices are not providing firm grounding for design, which is in turn not being systematically evaluated" (p. 57). In particular, most fieldwork has concentrated on narrow slices of the overall PIM problem (e.g., the numerous studies on email filing and management practices). My goal is to take a more holistic approach that can support next-generation PIM system design and research. Following this holistic approach, I identify opportunities for PIM system design in education that go beyond existing approaches (such as MyLifeBits' collections and annotations).

1.4 Summary

Technology investments for education should be closely tied to scientific knowledge about how students learn, and research into actual student behaviors and practices. The research presented here gathers data in these areas, and makes recommendations for educational technology that can help support students in new ways. This work has the potential to significantly improve PIM systems for students, and enable new forms of support for learning activities, such as reflection and metacognition.

Chapter 2: Conceptual framework

2.1 PIM Behaviors and Practices

In this section, I review research on people manage their personal information. Over approximately twenty-five years of research on personal information management (PIM), numerous behaviors, practices, and strategies have been identified and characterized. Some of this behavioral research has been applied to PIM system design, in an effort to build systems in accord with people's PIM needs (see Section 2.5, "Qualitative field research methods," for further discussion of user-centered design models). Research that focuses on developing and evaluating PIM systems and interfaces to support users is discussed in Section 2.2 ("PIM and capture systems technology") and Section 2.4 ("HCI support for PIM").

A goal of this research is to extend the current PIM knowledge base by taking a different perspective than that of most previous studies. To assist with this goal, this section focuses on distinguishing areas where there is a strong knowledge base with clear implications for system design from those where previous research is limited. I assess the state of knowledge in major areas of PIM behavior in order to identify fruitful opportunities for research and design.

Overall, my review of research in this area demonstrates that people want to understand and use their information within a personal collection (i.e., an information/task space) that makes sense to them, while minimizing the cognitive and metacognitive costs of filing, retrieving, and using information (Barreau & Nardi, 1995; Boardman, 2004; Ravasio et al., 2004). This finding is tempered by numerous gaps in the research literature. In particular, most studies focused on small groups of technical users, over short periods of time, and many are arguably out of date. Further research on PIM behaviors and practices is therefore warranted.

2.1.1 Definitions of PIM

To provide a scope for this review, it is useful to examine some basic definitions of PIM (see also Jones (2007)). Lansdale (1988) defines PIM as "the methods and procedures by which we handle, categorize, and retrieve information on a day-to-day basis" (p. 56). Barreau (1995) describes PIM more broadly as:

> A system developed by or created for an individual for personal use in a work environment… [Such a system includes] a person's methods and rules for acquiring the information … the mechanisms for organizing and storing the information, the rules and procedures for maintaining the system, the mechanisms for retrieval, and procedures for producing various outputs (p. 329).

A third and very useful definition, given by Jones & Bruce (2005), emphasizes that each individual manages a "personal space of information" which contains multiple "personal information environments."

2.1.2 PIM Tasks

Detailed descriptions of PIM tasks are needed to understand the scope of PIM research and design. Moreover, defining key tasks is important for building the theoretical and methodological foundations of PIM studies. Jones and Bruce (2005) identify eight primary tasks in PIM:

- search
- find
- encounter
- interpret
- decide to keep or not
- file and organize for re-use
- re-access
- use

The first four tasks are analogous to classic information-seeking tasks (Bruce, 1998; Marchionini, 1995; Saracevic, Kantor, Chamis, & Trivison, 1988). In contrast, *keeping*, *filing*, and *re-accessing* are distinctively characteristic of PIM, in that they involve managing and working with a personal corpus. The tasks can be compared with tasks supported by the CARPE (Continuous Archival and Retrieval of Personal Experiences) approach, which focuses on capturing and digitizing analog information from one's life experience, using ubiquitous computing technologies (Czerwinski *et al.*, 2006). Table 2 presents a summary of tasks supported by CARPE systems.

Table 2. CARPE tasks.

CARPE Czerwinski et al. (2006) identify five main tasks that CARPE can support:
Memory. Finding things (such as keys and eyeglasses); replaying learning and teaching experiences; reviewing research and travel; remembering names of people and places; and reviewing discussions and meetings;
Share personal experience. Reliving experiences with lost or distant loved ones; improving communication between grandparents and grandchildren; and sharing everyday events with people separated by distance;
Personal reflection and analysis. Understanding personal development; reviewing conflicts; finding situational patterns correlated to emotional states; and improving health via medical monitoring;
Time management. Improving productivity at and away from the workplace; improving coordination among family, friends, and co-workers; and identifying relevant or proximate information, given the

current context (including but not limited to location); and
Security. Using information for legal purposes (such as to resolve arguments and prove alibis); for security purposes (such as personal video recordings that might include evidence of, say, a possible terrorist in a public location).

In addition to these tasks, numerous studies have identified *reminding* and *task management* as important tasks closely associated with other PIM activities (Barreau & Nardi, 1995; Bellotti et al., 2004; Bellotti et al., 2003; Malone, 1983; Williamson, 1998). Other work has emphasized the importance of enabling people to "*make order*"—that is, to create personal collections that are ordered in meaningful ways (Barreau & Nardi, 1995; Henderson, 2005). Finally, within the educational context, *metacognition* and *reflection* have been shown to be central to effective learning (Hacker, 1998; Hacker, Dunlosky, & Graesser, 1998; Schraw, Crippen, & Hartley, 2006).

Synthesizing the various proposed PIM and CARPE tasks, I identify four major classes of tasks that PIM systems should support (see Table 3).

Table 3. PIM task classes.

PIM tasks

Refinding. Accessing information that one has acquired and stored in a PIM system (such as an email to a colleague, a report downloaded from a Web site, or a picture from a friend's wedding).
Reminding and task management. Keeping track of what projects and tasks one needs to work on, including key deadlines.
Making order. Filing or organizing as practices that help make sense of a complex stream of incoming data.
Reflection and metacognition. Improving metacognition, the "activities and skills related to planning, monitoring, evaluating, and repairing performance" (Teevan, Alvarado, Ackerman, & Karger, 2004), p.148. Reflecting on one's activities to understand them more deeply, and construct personal narratives.

The following subsections assess the research that has investigated these broad task classes in more detail.

Task 1: Refinding

PIM research has investigated "refinding," as opposed to "finding" behavior. *Finding*, typically referred to as "information seeking" (Bruce, 1998; Marchionini, 1995; Saracevic et al., 1988), involves looking for some unknown information based on an information need that can range from tightly defined (e.g., find a particular fact) to vague and exploratory (e.g., find something "of interest" in a general area). In contrast, *refinding* involves looking for information that one has already seen—"getting back to the information" (Capra & Pérez-Quiñones, 2005) (p. 38).

Refinding has been a primary focus of PIM research. In general, researchers have taken the view that individuals store data in their PIM systems (of any type), and then need to refind data when the need strikes as part of some other task. For example, one might meet a colleague at a conference in another city, and take her business card. Once home, the phone number is noted and the card thrown away. Several months later, it's desired to call the colleague regarding a possible collaboration; one remembers only her first name and the general experience of the conference; the refinding task is to locate the phone number.

Capra (2006) distinguishes three major influences on refinding task structure and difficulty: task type and complexity; individual domain knowledge and expertise; and time elapsed. However, it is unclear how these influences affect refinding in the PIM context. Capra argues that "many of the tasks addressed in PIM are directed information seeking tasks—in other words, they are concerned with finding specific information, the structure of which is probably known to the searcher" (p. 10). To an extent, this assumption is validated by previous research. Barreau and Nardi (1995) report users working primarily with "ephemeral" information tied closely to active projects. Users work regularly with this information, understand it well, and have little difficulty refinding it (Bruce, Jones, & Dumais, 2004). Accessing older, archived information is more difficult but largely unnecessary in typical work situations.

However, the fact that users have been show to have a good understanding of the structure of their information in their PIM system does not imply that they are engaging in "directed information seeking tasks" when refinding. In fact, one of the most prominent results from research on refinding is that users prefer to browse through collections of related information in a coherent structure, rather than simply accessing the needed information directly (Barreau & Nardi, 1995; Boardman & Sasse, 2004; Ravasio et al., 2004). Specifically, users generally prefer to "orienteer" rather than to "teleport" (Teevan et al., 2004). Orienteering is "a search behavior in which people reach a particular information need through a series of small steps" (Teevan et al., 2004), p. 417. In contrast, teleporting involves immediately retrieving a piece of information based on a specific request.

Why might users prefer to orienteer, when teleporting appears more efficient? Orienteering has been shown to have three key advantages over teleporting: *cognitive ease*, *sense of location*, and *understanding the answer* (Teevan et al., 2004). Orienteering is easier because it does not require users to explicitly articulate exactly what they are seeking—a general property of browsing that leads users to prefer it to searching in many situations (Marchionini, 2006). Orienteering allows users to feel in control as they navigate through a personal collection, maintaining a sense of context and avoiding the sensation of being "lost in hyperspace" (Ahuja & Webster, 2001; Eveland & Dunwoody, 2001). Finally, orienteering helps people make sense of the information they find, including ambiguous or negative results.

Although this specific analysis of orienteering behavior has yet to be validated by other research, several studies have confirmed that users prefer to browse rather than search their PIM systems (Barreau & Nardi, 1995; Boardman & Sasse, 2004; Ravasio et al., 2004). Given the consistency of this finding, most researchers have concluded that browsing is a fundamental PIM behavior that should be supported, rather than eliminated, by system design (Bergman, Beyth-Marom, & Nachmias, 2003; Boardman, 2004; Ravasio et al., 2004; Teevan et al., 2004). An alternative view is that improvements in search technology will gradually shift users' behavior, leading to a preference for search (Cutrell, Dumais et al., 2006). To resolve this debate, future research should seek to verify the specific costs and benefits of orienteering and teleporting behavior, as well as explore ways to improve and integrate both modes of access.

A second major concern in refinding research is *information fragmentation*. Users of modern desktop systems are often frustrated that their information is fragmented by application or file type (Bergman, Beyth-Marom, & Nachmias, 2006; Boardman & Sasse, 2004; Jones, Munat et al., 2005; Kaptelinin, 2003; Ravasio et al., 2004). For example, information used to prepare for a class presentation may be scattered across PowerPoint files, Word documents, emails, and Web pages (both local and remote).

It is broadly accepted that people think in terms of projects, tasks, and actions, rather than files and applications (Bergman et al., 2006). However, understanding of this problem from the users' perspective is still limited. Most research has focused on developing systems that can provide some level of integration (Bellotti et al., 2003; Jones, Munat et al., 2005; Kaptelinin, 2003). The research presented in this dissertation has been motivated, in part, by apparent deficiencies in current desktop PIM software (such as operating systems and email clients). It has been repeatedly observed that users are frustrated with current designs, and integrated systems seem like a reasonable design direction (Bellotti, Ducheneaut, Howard, Smith, & Grinter, 2005; Kaptelinin, 2003;

Ravasio et al., 2004). Nevertheless, it appears there has been little research on the underlying mental or conceptual models people rely on in PIM.

Task 2: Reminding and task management

Research shows that people manage their personal information to support their activities or tasks (Bergman et al., 2003; Boardman & Sasse, 2004; Jones, Munat et al., 2005). Thus, *managing tasks* is often as important as managing collections of information, particularly when one has a large number of complex tasks that extend over time (Bellotti et al., 2004). Users also need to be *reminded* of tasks, particularly when they have associated deadlines.

Research on reminding and task management practices indicates that users seek to organize and structure their projects, but often lack tools well-suited to this activity. Jones, Phuwanartnurak, Gill and Bruce (2005) have studied folder usage on modern desktop systems. They observe that "…re-access to personal information is not necessarily the sole or even the primary purpose of a folder organization… the folder structure for a project is frequently a problem decomposition" (Jones, Phuwanartnurak et al., 2005), p. 1506. That is, there is often a strong connection between refinding and reminding. People want to see and use documents in the context of tasks and projects. Projects are often complex—too complex to decompose and manage in one's head. As a result people have appropriated a range of systems to help offload this cognitive demand (Jacob, 2001; Kirsh, 2005). This offloading is critical for supporting creativity and reducing a sense of overload and stress (Allen, 2001).

Moreover, people rely on the sheer presence of items in a PIM system (both physical and digital) to remind them of tasks (Barreau & Nardi, 1995; Malone, 1983; Williamson, 1998). Research has examined the physical attributes of paper documents that support reminding and task management in real environments (Bondarenko & Janssen, 2005). People routinely move and group paper documents to create ad-hoc organizations associated with particular tasks (Taylor & Swan, 2004). For example, a family might put a communal notebook, containing tasks and shopping information on a kitchen table (Taylor & Swan, 2004). Research indicates that people can easily make use of tangible attributes (such as the size of a document or physical folder, location on a desk or within an office or relative to other documents) to quickly assess the purpose of a document and its relationship to ongoing tasks. Kirsh (2001) identifies three underlying purposes for these types of uses: "entry points," "activity landscapes," and "coordinating mechanisms:"

> An *entry point* is a structure or cue that represents an invitation to enter an information space or office task. An *activity landscape*… is the space users interactively construct out of the resources they find when trying to accomplish a task. A *coordinating mechanism* is an artifact, such as a schedule, or clock, or an environmental structure such as the layout of papers to be signed, which helps a user manage the complexity of his task (p. 305).

Thus a journal left on a desk, opened to a particular page, may serve as an entry point to reading the complete article, when time becomes available. A folder full of photocopied articles may serve as an activity landscape for citation checking. A group of sticky notes attached to a monitor, each containing a brief reference or idea, may function as a coordinating mechanism which simplifies the writing process. Research has also indicated that the strictly material and spatial aspects of information (in either the digital or the physical space) are only part of the picture (Taylor & Swan, 2004). The very arrangement of documents on a desk, for example, is associated with a rich "folklore" based on local conventions and cultural practices (e.g., how "neatness" and "messiness" are perceived within a workgroup) (Neumann, 1999).

Ease is a key factor in how people choose to structure their PIM systems for reminding and task management. Paper has proved remarkably resilient in the face of huge advances in digital technology and desktop software, simply because it is easier to work with in many cases (Bondarenko & Janssen, 2005). Paper is easier to glance at and assess, easier to read, easier to annotate, easier to use as a spatial cue, easier to group and regroup, and even easier to share and collaborate with in some cases. For example, moving a paper across a desk feels intuitive and effortless, perhaps because it is a fully *embodied* interaction, that engages the perceptual and motor systems (Dourish, 2001). In contrast, research shows that refiling a digital document often feels cognitively effortful and undesirable (Bondarenko & Janssen, 2005; Smith et al., 2006).

Understanding the affordances and uses of different media and systems is an important component of the larger issue: developing effective models or theories of task management and reminding *behavior*. Over twenty years ago, it was argued that "by explicitly trying to facilitate reminding, computer-based systems may become even more useful. To design such systems will require a better understanding of the subtleties of human scheduling, procrastination, and forgetting" (Malone, 1983) p. 110. Though much progress has been made, it seems this understanding has not yet been fully developed. We know that people have many tasks to keep track of, that they embed reminders throughout their physical and digital environments, and yet in many cases they still feel anxiety about keeping track of tasks and deadlines. Indeed, a rich self-help literature offers numerous organization strategies intended to improve reminding effectiveness (Allen, 2001; Morgenstern, 2004). What is needed to inform PIM system design is a deeper understanding of *how* and *why* people manage their tasks and create reminders, and how they use these structures in their day-to-day activities. In particular, study of task management practices in different domains and situations is needed. As this discussion demonstrates, much of the research has focused primarily on knowledge workers and managers (Bellotti et al., 2004; Boardman & Sasse, 2004).

Task 3: Making order

It has long been observed that creating information structures and classifying one's personal information can be cognitively demanding and tedious (Barreau & Nardi, 1995; Cutrell, Dumais et al., 2006; Luescher, 2004; Malone, 1983; Smith et al., 2006). Why, then, do people bother? It must be because the benefits outweigh the costs in some instances. The structures people create must add value to their PIM systems and practices in some way. And, in fact, the research on refinding practices indicates where this value might lie. As discussed previously, people generally prefer to "orienteer" rather than "teleport." Orienteering has three key advantages over teleporting: *cognitive ease*, *sense of location*, and *understanding the answer* (Teevan et al., 2004). To be able to exploit these advantages, users must have access to a well-structured personal information space. In other words, users must "make order" within an otherwise chaotic information space.

The concept of "making order" is evident in field studies of classification and metadata creation practices (Bowker & Star, 1991; Dourish, 2000; Levy, 1995; Marshall, 1998; Trigg, Blomberg, & Suchman, 1999). In the process of developing and assigning metadata, catalogers (and other metadata creators) codify the intellectual structure of the collection as a whole. Marshall (1998) describes this work as "mapping the territory" of collections. Users in social bookmarking systems (Hammond, Hannay, Lund, & Scott, 2005; Smith et al.,

2006) take on similar roles. This process is mirrored in PIM, as users develop folder structures based on personally meaningful classifications such as task and genre (Henderson, 2005).

Making order in PIM environments appears to have three main purposes (Boardman & Sasse, 2004; Bondarenko & Janssen, 2005; Bruce et al., 2004; Cutrell, Dumais et al., 2006; Jones, 2004). First, it supports the browsing-based refinding which people prefer, particularly when looking for unfamiliar information (i.e., information not in the immediate working space or a "hot" project). Second, people desire personal collections that "make sense." It is reassuring to know that one's digital files are organized in some meaningful way, and a "sensible" collection can support functions beyond browsing and refinding (Cutrell, Dumais et al., 2006; Jones, Phuwanartnurak et al., 2005). People seek a sense of control over the personal information that can counterbalance the anxiety and angst of possessing huge amounts of chaotic information (Jones, 2004). Some research indicates that making order is closely intertwined with making "keeping decisions," such as whether to save, archive, and organize a given information object (Jones, 2004). Moreover, having a persistent and stable personal information space may be valuable because it allows people to become comfortable and efficient working within it (Boardman & Sasse, 2004; Bondarenko & Janssen, 2005; Bruce et al., 2004). At the same time, people need the ability to integrate new information or new references with ongoing projects and existing organizational schemes (Bruce et al., 2004).

It is also important to consider the *process* of order-making as well as its *products*. "Making order" and the cognitive costs of classification (Malone, 1983) are two sides of the same coin. Classification serves as "cognitive scaffolding" (Jacob, 2001) and the act of classifying is itself a process of learning and making sense. Thus, making order is valuable not only because it results in a browsable, sensible collection, but because the very act of making order increases one's understanding of and engagement with the information. Johnson (2003) emphasizes the importance of framing: "putting a perspective into words when one encodes a message" (p. 744). In other words, making order is about applying one's distinct perspective and point of view to the PIM system—it is about creating an "information field," an "arrangement of information stimuli" that matches one's personal perspective (J. D. Johnson, 2003) (p. 750).

Field studies indicate there is great variety in how people make order within their PIM systems, but general themes and patterns can be identified. Boardman and Sasse (2004) found three key influences on participants' filing strategies. First, the *perceived value of information* influences the PIM strategy chosen. Files were generally highly organized, while email was organized loosely or not at all. Second, the *likelihood and style of retrieval* influences the method and intensity of organization. If one does not expect to refer to a file again, there is little point in filing it carefully. Third, the *acquisition mode* influences organization. Files are generally organized as they are created, whereas email arrives comes in a single, unorganized stream and must be filed afterwards.

Other research has attempted to tease out the specific organizational strategies that people employ (Barreau, 1995; Henderson, 2005). These studies examine what personal information architectures look like in practice. To the extent that these architectures can be characterized they may provide a valuable foundation for system design. In general terms, we can say that PIM systems should enable users to create personal collections that can be flexibly organized in meaningful ways and contain meta-information about content, context, and structure (Cox, 2001; Gilliland-Swetland, 2000; Greenberg, Crystal et al., 2006). This approach is discussed in more detail in Section 2.3, "Metadata in PIM." However, it is critical that support for making order not be narrowly construed as support for "filing." Identifying precise user needs and goals in this area is difficult, both because of highly personal nature of making order, and the limited research focused on this issue. But it is clear that making order is closely tied to understanding and applying a point of view to a personal collection. This larger perspective is an important aspect of PIM research, and a fundamental topic in my research.

Task 4: Reflection and metacognition

Metacognition is a component of the general psychological ability of "self-regulation" (Hacker, 1998). Metacognition is essential to learning and being able to apply what one has learned. Metacognition comprises two broad areas: "knowledge of cognition" and "regulation of cognition" (Schraw et al., 2006). Knowledge of cognition includes *declarative* knowledge (i.e., knowledge "about ourselves as learners"), *procedural* knowledge (i.e., knowledge "about strategies"), and *conditional* knowledge (i.e., knowledge about "why and when to use a particular strategy"). In contrast, "regulation of cognition" encompasses *planning* ("selection of appropriate strategies and allocation of resources"), *monitoring* ("self-testing skills necessary to control learning"), and *evaluation* ("appraising the products and regulatory processes of one's own learning").

Metacognitive processes in general tend to be highly automatized–that is, they are often developed without conscious reflection and processing. Reflecting on one's activities (and particularly for students, one's learning processes) can help develop further develop metacognitive abilities. Ishii & Miwa (2005) argue that engaging students in reflection can help them realize the characteristics of creative processes and learn the importance of metacognitive activities. *Reflection* can be seen as much more than an aid to metacognition and learning. In particular, reflection can help support professional development, personal growth and building a "life story" (McAdams, 2001). Levy (2005) argues for the importance of enabling reflection and contemplation in an accelerated environment of pervasive information overload.

While metacognition has been extensively studied in psychology and education, reflection is a relatively new area of inquiry. Because both of these activities are closely related, and tied to the broader concern of self-regulation, I consider them together. While both concepts have been studied, the idea that PIM systems could support them is still nascent. However, Czerwinski et al. (2006) do explicitly highlight "reflection and personal analysis" as a potential goal of CARPE systems. This is one of the first formal statements linking system and interface support to reflection (and implicitly, metacognition). A key challenge for PIM research is to develop an understanding of how people engage in reflection and metacognition in practice, and then apply this understanding to system design. Specifically, systems must support reflection and metacognition in new ways that go beyond existing tools, such as pencil-and-paper journals.

A number of disciplines have begun to examine metacognition. In particular educational researchers, in disciplines such as mathematics and science, have focused on metacognition's role in learning (Schraw et al., 2006). Hershkowitz & Schwartz (1999) examined reflective processes in middle-school mathematics classes. They found that reflection is *fundamentally social*, and grounded in particular forms of *discourse* (such as debate and explanation). This social structure creates a need for shared artifacts to ground the discourse. Reflection is also about *perspective*, as students need "to distance themselves in time and perspective from previous actions and to reflect on their problem-solving process" (p. 81). When this perspective is successfully adopted, students "purify" their initially messy process of discovery and learning into a meaningful and memorable structure. Based on these findings, classroom processes that support reflection can be developed. Hershkowitz & Schwartz (1999) described a process in which students moved from problem solving, to creating a group report with classmates, to participating in a class discussion with other groups, to writing an individual report as homework. This combination of group discovery, debate, and individual reflection led to effective "purification."   To support reflection, users need raw material—something to reflect *on*. In a study of reflection among engineering students, it was found that "if participants had been given no information on their processes, they would have forgotten their own detailed processes" and so been unable to reflect deeply on their work (Ishii & Miwa, 2005), p. 156.

At a more general level, Kolb's (1984) experiential learning cycle models reflection (see Figure 1).

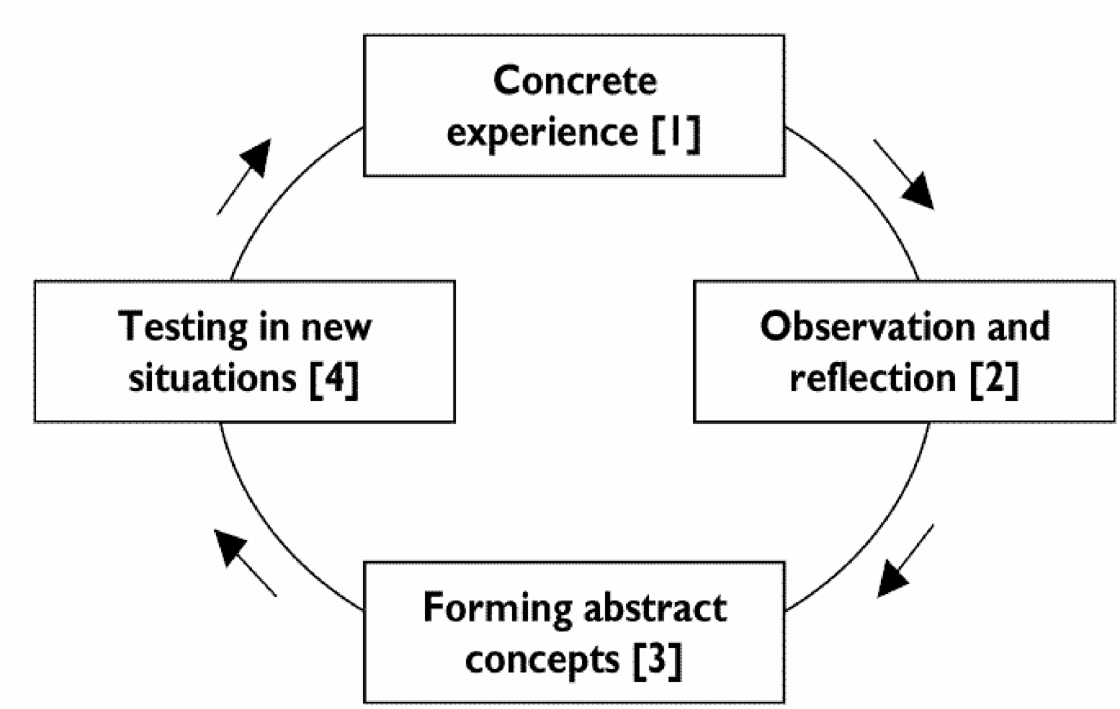


Figure 1. Kolb's (1984) model of experiential learning includes reflection. (Diagram source: http://www.infed.org/images/explrn.gif).

This model specifies how reflection fits with experience and learning, but not the specific outputs of reflection. Moon (1999) identified ten potential outputs of reflection:

1. Learning and the material for further reflection
2. Action or other representation of learning
3. Reflection on the process of learning
4. Critical review
5. The building of theory

6. Self-development
7. Decisions or resolutions of uncertainty
8. Empowerment or emancipation
9. Other outcomes that are unexpected – images or ideas that might be solutions
10. Emotion

These outputs of reflection can be used as a basis for designing support for reflective activity. Overall, the research on metacognition and reflection has developed some clear models and theory, and explored how students in actual classes (mostly K - 12) engage in metacognition and reflection. In addition, some basic design principles for systems that support metacognition and reflection have been developed (see Section 2.4, "HCI support for PIM," for more details on these principles). However, little work directly examined the connection between systems (particularly PIM/CARPE systems) and practical metacognition/reflection.

Metawork

Jones and Bruce (2005) describe the importance of "M-level" activities in PIM. These include *mapping*, *maintaining and organizing*, and *meta* activities. *Metawork* may be defined as 'working on one's work practices and systems.' People often ask questions such as:

- ‘Is my system working for me?’
- “Are the structures we’ve selected maintainable?”
- “Are the strategies we try to follow sustainable?”
- “Is this tool really helping or is it more trouble than it’s worth?” (Jones & Bruce, 2005), p. 15.

These questions are typical of metawork. This type of activity is sometimes referred to as “articulation work” (Bellotti et al., 2004; Strauss, 1988) because it involves articulating one’s needs and finding strategies and systems to support them. Little research has directly examined this activity, but comments in numerous PIM studies indicate that managing one’s systems is a common and important task. For example, Boardman and Sasse (2004) found participants began to reconsider and change their practices over the course of their study. It appears that metawork is an open area for research that can extend current understandings of PIM practices.

2.1.3 Conclusion

This section discussed how people “do PIM”—the strategies and practices they use to process, organize, manage, and retrieve information in support of their work and life. PIM systems were defined broadly as “a person’s methods and rules for acquiring the information … the mechanisms for organizing and storing the information, the rules and procedures for maintaining the system, the mechanisms for retrieval, and procedures for producing various outputs" (Barreau, 1995), p.329. People use PIM systems to support four key tasks:

1. refinding
2. reminding and task management
3. making order
4. reflection and metacognition

These tasks are typically not ends in themselves, but are embedded in larger tasks and projects. For example, one might search for an email address to be able to find a potential job lead for a friend. Or one might retrieve and reflect upon recent tasks in order to better structure weekly schedules, and become more productive. In addition, the task of metawork involves reflecting upon and updating one's PIM practices and system.

Within this broad framework, many detailed field studies have been conducted. Synthesizing these studies, the key theme that emerges is that people want to understand and use their information within a personal collection (i.e., an information/task space) that makes sense to them, while minimizing the cognitive and metacognitive costs of filing, retrieving, and using information.

Boardman (2004), following Whittaker, Terveen, & Nardi (2000), makes a strong critique of existing PIM research: “PIM has not received the attention it merits as a fundamental computer-based activity” (p. 57). Furthermore, “there is no accepted body of knowledge to build further research on, for example a consensus of people's tasks and problems, and appropriate metrics for evaluation” (Boardman, 2004), p.38. This is partly due to a lack of intensive, longitudinal research on PIM, which could build richer models of tasks and examine changes in strategies over time. In addition, most studies have focused on small groups of technical users, neglecting a range of other users, from students to non-technical specialists to home users, such as mothers (Taylor & Swan, 2004). Finally, many oft-cited studies are over a decade old, and both user needs and the technical infrastructure have changed considerably in that time. In addition to these criticisms, it appears that PIM research has focused too narrowly on organization and retrieval, neglecting broader problems. Considering these issues, it appears there is substantial potential for further research on PIM.

2.2 PIM and capture systems technology

2.2.1 Introduction

This section covers the technical infrastructure available to support PIM tasks. I focus on how the key technical approaches support the main PIM tasks that have been identified in previous PIM and HCI research: *refinding, reminding and task management*, *order-making*, and *reflection and metacognition* see section 2.1, "PIM behaviors and practices," for detailed discussion of the user practices and behaviors underlying these tasks). For example, one of the main user tasks in PIM is refinding. Caching and indexing of browsed Web pages are technical approaches that support refinding of these pages.

This section presents a framework developed for analyzing these technical approaches. The framework identifies three main classes of systems: PIM systems, CARPE systems, and context-sensing systems. I analyze specific systems that address the main functional issues. Since many systems support various elements of the broad functions that comprise my framework, I have selected a subset of systems that are specifically relevant to context-aware PIM on a personal computer. My goal is to summarize the state of the art in capture system support for PIM, so that opportunities for technically realistic design solutions are apparent. This section, along with Section 2.3 ("Metadata in PIM") and section 2.4 ("HCI support for PIM") summarize the current design space for PIM systems.

2.2.2 Capture: PIM vs. CARPE Approaches

To manage our personal information digitally, we must first capture it. Many systems perform some kind of capture, in different ways, for different types of data. Two broad approaches to the idea of "capture" can be contrasted: the PIM approach, which focuses on collecting and managing digital information, typically on a PC (Jones & Bruce, 2005); and the CARPE (Continuous Archival and Retrieval of Personal Experiences) approach, which focuses on capturing and digitizing analog information from one's life experience, using ubiquitous computing technologies (Czerwinski *et al.*, 2006). Table 1 presents key user tasks identified by CARPE researchers, and Table 2 presents key user tasks identified by PIM researchers.

Table 4. User tasks from CARPE perspective.

CARPE Czerwinski et al. (2006) identify five main tasks that CARPE can support:
Memory. Finding things (such as keys and eyeglasses); replaying learning and teaching experiences; reviewing research and travel; remembering names of people and

places; and reviewing discussions and meetings;
Share personal experience. Reliving experiences with lost or distant loved ones; improving communication between grandparents and grandchildren; and sharing everyday events with people separated by distance;
Personal reflection and analysis. Understanding personal development; reviewing conflicts; finding situational patterns correlated to emotional states; and improving health via medical monitoring;
Time management. Improving productivity at and away from the workplace; improving coordination among family, friends, and co-workers; and identifying relevant or proximate information, given the current context (including but not limited to location); and
Security. Using information for legal purposes (such as to resolve arguments and prove alibis); for security purposes (such as personal video recordings that might include evidence of, say, a possible terrorist in a public location).

Table 5. User tasks from PIM perspective.

PIM
There are four main tasks that PIM can support. I have derived these tasks from previous research on PIM practices (Barreau & Nardi, 1995; Capra, 2006; Kirsh, 2005; Marshall, 1998). See section 2.1, "PIM behaviors and practices," for detailed discussion of these tasks and supporting references).
Refinding. Accessing information that one has acquired and stored in a PIM system (such as an email to a colleague, a report downloaded from a Web site, or a picture from a friend's wedding).
Reminding and task management. Keeping track of what projects and tasks one needs to work on, including key deadlines.
Making order. Filing or organizing as practices that help make sense of a complex stream of incoming data.
Reflection and metacognition. Improving metacognition, the "activities and skills related to planning, monitoring, evaluating, and repairing performance" (Kirsh, 2005, p. 148), p.148. Reflecting on one's activities to understand them more deeply, and construct personal narratives.

In general, PIM systems development has been primarily concerned with "information fragmentation" (Jones, Munat et al., 2005) and "project fragmentation" (Bergman et al., 2006). It is broadly accepted that people think in terms of projects, tasks, and actions, rather than files and applications. Users of modern desktop systems are often frustrated that their information must be accessed by application or file type, rather than by project or task (Bergman et al., 2006).

PIM systems attempt to provide access in an integrated way across multiple object/document formats, applications, and information structures (e.g. file folders and email folders), thereby addressing the fragmentation problem. In contrast, CARPE systems attempt to provide access to new forms of information, including experiences that would never be recorded and indexed (other than by human memories). Despite these different foci, both CARPE and PIM systems address a number of the same user needs and goals. These needs and goals include recalling half-remembered bits of information, reflecting on one's life and work, making sense of a complex world, and keeping track of what one has committed to doing (for example tasks, to-do's and deadlines).

This review summarizes representative PIM and CARPE system approaches, with a focus on establishing a technical basis for designs that use elements of both the CARPE and PIM perspectives, as well as some of the major approaches for using sensors to detect and infer elements of "context" (the challenges of defining and representing context are discussed in section 2.3, "Metadata in PIM").

2.2.3 PIM Systems

This section discusses PIM systems, focusing on systems that have addressed information and project fragmentation, as these concepts are particularly relevant to the challenge of designing PIM systems to support students. Three major approaches—*indexing, layering*, and *databases*—have been identified, and provide a framework for discussing system capabilities. *Indexing systems* are focused on applying information retrieval techniques to personal information collections. *Layering systems* are designed to address fragmentation by providing a higher-level, more abstract view of information than operating systems and individual PIM applications. *Database systems* store many types of information in a single database, allowing more powerful forms of management and retrieval. The following subsections discuss each of these three approaches in turn.

Indexing

One of the main challenges in designing PIM systems for large-scale personal collections is indexing and searching the information store (Komlodi, Marchionini, & Soergel, 2007). Theorists have long debated the most effective methods for indexing personal collections, with Bush's original Memex proposal arguing for supplanting classification schemes with associative linking (Bush, 1945). Buckland (1992) argued that Bush's criticism of classification was naïve and that associative linking has only limited value. Although this debate remains important, modern systems generally draw on multiple approaches, combining elements of classification, linking and automatic indexing using information retrieval techniques. We can distinguish between *application-specific* PIM systems, which capture and index particular data types or classes, and *integrated* systems, which capture and index many different data types and provide retrieval functions across the types.

An *application-specific indexing tool* is a system that indexes a single data type or application on a PC. Commercial email indexing tools, such as LookOut (Luescher, 2004), build an index of a user's saved email messages, and add new messages to the index as they arrive. These tools may index on multiple object attributes (e..g, "date," "subject" and "author" for email messages), but they are limited to a specific application. These dedicated tools have largely been superseded by commercial implementations of integrated desktop search systems (Gemmell, 2006), discussed below.

An *integrated indexing tool* is a system that indexes multiple data types or applications on a PC, and provides a single retrieval interface that operates across these different types. Stuff I've Seen (Dumais et al., 2003) demonstrated that it was feasible and useful to provide integrated access to a range of file types (documents, emails, Web pages, etc.) using a single index and interface. While these different types of files are associated with distinct applications, they are all largely textual, making integrated indexing and search feasible. Many users find it helpful to be able to conduct searches of their personal file systems on demand, and the integrated indexing approach has been refined into commercial tools, such as MSN Desktop Search, Copernic Desktop Search, and Google Desktop. Meanwhile, research continues to investigate ways of improving this approach by incorporating additional sources of information (such as personal tags) into the system (Cutrell, Robbins, Dumais, & Sarin, 2006; Richter, Miller, Abowd, & Hsi, 2005).

While integrated indexing tools for textual files have become widespread, research continues on application-specific indexing tools for specific types of multimedia. Because content-based image retrieval is still fairly primitive (Veltkamp & Tanase, 2002), researchers have investigated methods for capturing and indexing photographs with rich technical content and concept metadata (see Rasmussen (1997) for a thorough review). ButterflyNet (Yeh et al., 2006), for example, combines a camera that supports on-the-spot annotations with a digital pen system, enabling field biologists to create paper notebooks seamlessly linked to digital photographs via associative metadata. The photographs can be also associated with tagged specimens from the field, and linked with sensor data. RAW (Jo, lle, Stefan, & Matthew, 2004) supports annotation of photographs with audio from immediately before and immediately after the picture is taken, allowing "users themselves to reflect more directly on their everyday lives" (Jo et al., 2004) p. 495.

Layering

A major focus in PIM research has been dealing with the fragmentation of information related to an activity or project. The hierarchical file structures and disparate file formats of modern operating systems have made this fragmentation endemic to a typical knowledge worker's computing tasks (see Section 2.1 for further details on the fragmentation problem). Desktop search systems (even highly integrated ones) deal with this problem only superficially, because users generally do not search for local files (Ravasio et al., 2004). Numerous systems have been developed to address fragmentation by providing a data layer at a higher level of abstraction than the individual files managed by operating systems and applications (see Figure 2). This dissertation refers to such systems as *layering systems*.

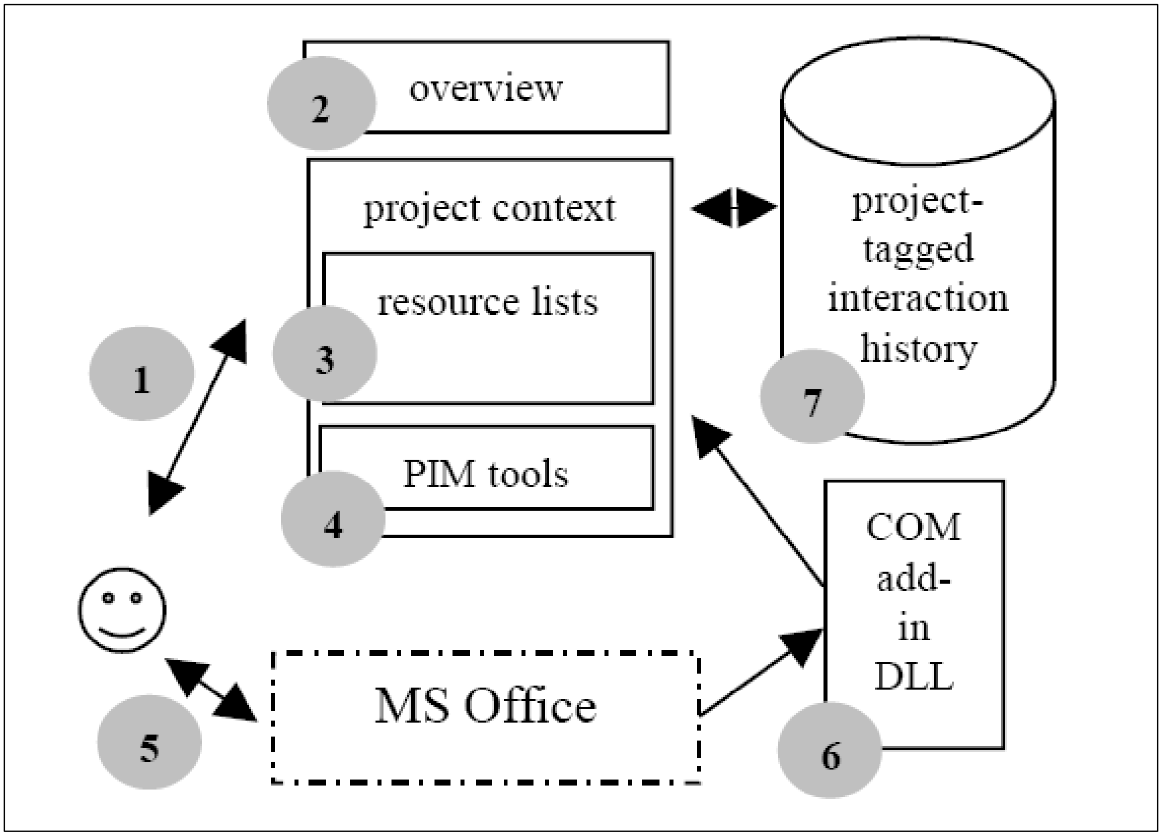


Figure 2. Model of the UMEA layering system (Kaptelinin, 2003).

The first systems of this type worked by extending existing applications, such as Microsoft Office. UMEA (Kaptelinin, 2003), for example, monitors file usage by multiple applications to provide a unified history of a user's activity. This history is integrated into a high-level "project view" with a calendar, task list, and so forth. Analogously, Iolite uses agents to discover associations between files, emails, and tasks (Rothrock, Myers, & Wang, 2006). Taskmaster (Bellotti et al., 2003) takes a similar approach, but from an email-centric perspective. Taskmaster enables multiple file types, actions, and reminders to be managed as a single “thrask” (threaded task) in an email client. The thrask can be considered a layer above email, task management, and individual office applications.

Other systems have extended the layering model to include rich semantic associations, often based on Semantic Web (Miller, 2002) models. Haystack (Karger, Bakshi, Huynh, Quan, & Sinha, 2003) uses a semistructured data model, based on RDF, that allows flexible creation of collections of information objects (Karger & Quan, 2004). For example, a virtual “inbox” might contain email, stories from RSS feeds, and contact information of individuals. Similarly, SEMEX (Dong & Halevy, 2005) attempts build a database of instances and associations from a user’s personal information store, and integrate these with external information sources. These instances and associations support querying and browsing, as well as ubiquitous computing tasks such as context awareness and coordination among multiple personal devices. Another example of this approach is mSpace (schraefel et al., 2005), an interaction model based on Semantic Web frameworks and analogous to both Haystack and SEMEX. mSpace was designed to support rapid exploration of large Web-based collections, but could also be applied to personal collections.

Overall, the layering approach to PIM has proved effective in evaluations (Bellotti et al., 2003; Kaptelinin, 2003). However, making the layering useful has generally required integrating it tightly with particular applications and file formats. Efforts to produce more generic layers that can flexibly handle a wide range of information types are still in the exploratory stages.

Databases

An alternative to the layering approach is to build a large personal database that can contain many different types of information. Several PIM systems have also taken this approach. MyLifeBits (Gemmell et al., 2006) is one of the most developed systems, and the test system for this research. MyLifeBits is frequently referred to as the exemplar of the database approach (Komlodi et al., 2007). MyLifeBits is based on a SQL Server database containing data and metadata for many types of objects, such as personal contacts, documents, Web pages, email, events, photos, music, and video. Each object type is represented by its own table in the database, which allows MyLifeBits to be continually extended to include new data types. Items in the database can be linked together, annotated, and combined into collections.

PICASSO (Guven, Podlaseck, & Pingali, 2005) is similar to MyLifeBits in that it uses a single, integrated database for many types of objects. It differs in that it emphasizes tagging, and using access to intranet data and services to support "personal chronicling" in an enterprise environment. PICASSO supports integrated tagging within any application by adding a "tag this" button to the standard Windows UI. These tags are integrated into interfaces for browsing and querying, such as an "Event Navigator" timeline view. PICASSO also enables captured items to be easily shared with colleagues on the intranet.

As with the layering systems discussed above, a generic approach is desirable but difficult to make viable in practice. More specialized systems designed for particular users and domains can be more effective, at the cost of generality. The Electronic Lab Journal (Fakas, Nguyen, & Gillet, 2005) is an example of a specialized PIM database for students, designed specifically for engineering classes. This system uses a "fragment" model analogous to MyLifeBits's item database. Students upload and work with typed fragments (documents, lab results, images, etc.). They can annotate and share these fragments (e.g., a student might send a question to TA with an attached fragment). The Electronic Lab Journal integrates with other specialized software (such as an experimentation applet, or data analysis component), and supports group awareness through visible activity traces (who is creating fragments, etc.). This specialized system provides richer functionality in the areas of annotation, sharing, and integration, but had to be custom-designed for a particular domain (education).

Summary

Numerous systems have addressed the technical challenges of capturing, storing and indexing personal information on the desktop PC. It is now technically feasible to meet a primary PIM goal—integrating different information types into a integrated store. However, it is still challenging to build a useful and usable PIM system. In particular, much systems research has aspired to universal solutions—MyLifeBits is "a personal database for everything" (Gemmell et al., 2006); Haystack and SEMEX seek to provide comprehensive models for PIM storage, organization, and retrieval. It seems the most successful systems in practice are often those tailored to particular user groups and tasks, such as the Electronic Lab Journal (Fakas et al., 2005) and ButterflyNet (Yeh et al., 2006). Since building custom PIM solutions for every domain remains unappealing due to cost and integration challenges, future systems development should seek to balance general and specialized approaches, and at least find solutions that work for classes of domains and users.

2.2.4 CARPE systems

As discussed above, the CARPE (Continuous Archival and Retrieval of Personal Experiences) approach focuses on capturing and digitizing information from one's life experience, using ubiquitous computing technologies (Czerwinski *et al.*, 2006). CARPE systems continuously monitor data inputs (such as, cameras, audio recorders, and activity on PC's and other devices), capture the data, and index and store it for later access. The goal is to augment people's sensory systems and memory, and allow people to directly see and interact with captured information.

The SenseCam (Cherry, 2005; Gemmell, Williams, Wood, Lueder, & Bell, 2004) is an example of a CARPE device. The SenseCam is a wearable camera which uses onboard sensors to take automatically pictures at "useful" or "interesting" moments (for example, when a person approaches for the first time, activating the infrared sensor). Cameras have also been integrated into eyeglasses (Cheatle, 2004), making them even less obtrusive than the SenseCam, which is designed to be worn on a lanyard around the neck. Next-generation approaches to wearable cameras include Mediated Reality (Mann, 2004; Mann & Fung, 2002; Nack, 2005), which acts as both a camera and a display, allowing augmentation and display of images as they are captured.

Many systems have also been designed to capture audio. Tivoli (Moran et al., 1997) was motivated by the need to refer back to discussions of complex technical issues. The system combined audio capture with notes from an electronic whiteboard. Tivoli was field-tested successfully at Xerox PARC and found to enhance work involving the management of intellectual property. The Personal Memory Aid (Vemuri, Schmandt, Bender, Tellex, & Lassey, 2004) combined a PDA with speech-recognition software on a server. This design enabled the capture of daily conversations and automatic creation of browsable and searchable transcripts. This approach was found to be useful for specific tasks, such as reviewing particularly important conversations with a supervisor, but in general audio quality and transcript quality were poor (Vemuri et al., 2004).

Even more sophisticated systems have attempted to continuously capture and index both video and audio. The LifeLog (Aizawa, Tancharoen, Kawasaki, & Yamasaki, 2004; Hori & Aizawa, 2003) combines continuous audio/video capture with sensors, enabling support for tasks such as 'Review the conversation I had with my friend Kim yesterday afternoon.' Because this approach generates such extensive amounts of multimedia data, LifeLog uses summarization and indexing techniques and contextual metadata to make retrieval more feasible. For example, pattern recognition algorithms can detect scenes that resemble conservations. The researchers argue these techniques will be effective in practice, but further evaluation with realistic data is needed.

CARPE systems can also be embedded in an environment, such as a classroom. These embedded CARPE systems are an alternative to a personal, wearable CARPE system like the SenseCam or Personal Memory Aid. The goal of eClass (Brotherton & Abowd, 2004) is to "preserve as much as possible of the lecture experience, with little or no human intervention" (p. 124). eClass automatically creates a Web site with audio and video from a lecture, Web pages the instructor visited in class, and annotated slides from the class. Students can visit the site at any time to review the lecture and accompanying notes and slides. eClass has been deployed and evaluated in several classes at Georgia Tech and Kennesaw State University. Students used the system extensively, and had a positive response to it. In controlled comparisons between two sections of the same class (where one section used eClass and one did not), no difference in student grades was found (Brotherton & Abowd, 2004). The researchers suggest that future systems should have better integration between captured media (audio, video) and captured artifacts (like annotated slides). ePresence (Baecker, Wolf, & Rankin, 2004) and the Digital Chemistry Project (Cuthbert et al., 2005), which are focused on interactive Webcasts, also provide similar archiving and retrieval of class lectures.

2.2.5 Summary

Researchers have developed many innovative techniques while pursuing general-purpose CARPE systems such as a LifeLog. Overall, the technical and functional capabilities of wearable CARPE systems have improved markedly over the last few years, and researchers speak confidently about being able to capture and store a lifetime's worth of audio and video (Aizawa et al., 2004). Progress has also been made in improving retrieval based on particular scenarios, but there seems to be a large gap between current research systems developed to serve general purposes and systems that people can use in their daily lives. In contrast, embedded CARPE systems such as eClass and ePresence have been successfully deployed on a fairly large scale (used by thousands of students over extended periods of time). However, these systems are constrained in many ways—in particular, they rely on integration with a fixed environment and a particular domain. eClass and ePresence, for example, depend on both a classroom, and on a particular style of teaching (slide-based lectures). These constraints illustrate the limitations of a CARPE system designed specifically for classroom environments. I emphasize these constraints because my research is focused on education, but analogous constraints could be identified for CARPE systems embedded in other environments and domains.

There remains a vast experience gap between PIM and CARPE. Millions of people use Microsoft Outlook daily to perform basic PIM activities, such as email and task management, but only a few researchers have used personal, wearable CARPE systems daily (Gemmell et al., 2006). The goal of the field research conducted for this dissertation was to help explore the daily experience of PIM and CARPE systems in order to identify areas where further technical innovation will help improve the users' experience. In particular, this work examines how the technical capabilities discussed here can support the four main PIM tasks presented in Table 1 above (refinding, reminding and task management, making order, and reflection and metacognition). This work also focuses on identifying areas where the capabilities of PIM and CARPE systems can be usefully combined to create new forms of support.

2.2.6 Context-sensing systems

As the discussion of CARPE systems has already noted, some systems incorporate environmental or physiological sensors to help improve indexing and retrieval of captured data. These sensors are often described as being able to capture some of the "context" of a user's activity. For example, a GPS sensor provides a nearly exact location. Captured audio can be associated with a location, enabling scenarios such as this one: "Listen to the conversation I had while in Mulberry Park." This simple notion of "context" is somewhat problematic, as Section 2.3 ("Metadata in PIM") discusses in more detail. However, we can still consider current implementations of sensing systems that provide a number of elements of context in PIM and CARPE systems.

Researchers have identified four primary components of context (Bradley & Dunlop, 2005).

- *task*—the activity or function in which a user is engaged
- *physical*—the user's physical environment, including location, temperature, weather, and so forth
- *social*—other people with whom the user is engaged in some way

- *temporal*—the present time, as well as the influence of past activities, and anticipated future activities

These components can be used as a framework for examining context-sensing systems. Systems have been developed to capture elements of each of these components, and examples of each are discussed in the following subsections.

Task

Task refers to the activity or function in which a user is engaged (Bradley & Dunlop, 2005). In one sense, task is the component of context least susceptible to system detection. "Working on a task" is entirely subjective, and one may appear to be engaged in a task while actually thinking about something else entirely. In another sense, typical tasks in particular domains likely exhibit characteristics that a system can detect and infer. For example, if a user opens a task list and email client and switches between these applications over a period of time, it could be inferred that the user is focused on task management.

TaskTracer (Dragunov et al., 2005) monitors users' interaction and attempts to recognize tasks using machine learning. This automatic recognition of tasks could enable both adaptive, task-specific interfaces and automatic classification of captured data by task. This recognition capability would complement activity-based interfaces (Bardram, Bunde-Pedersen, & Soegaard, 2006) that provide users extensive manual control over task and window management. Systems incorporating/supporting automatic classification of tasks based on users' interaction need to demonstrate a fair level of accuracy if they are to be trusted and used. This is because inaccurate classification can obstruct the users' ability to successfully complete underlying PIM tasks, such as refinding and task management.

PHYSICAL

Physical context includes the user's physical environment, such as location, temperature, weather, and so forth (Bradley & Dunlop, 2005). Much attention has focused on detecting and capturing physical elements of context. The SenseCam, for example, detects changes in light levels that may represent a change in location. GPS is used in many types of systems to determine location. Network data (e.g., Wi-Fi triangulation) can also be used to determine location within the reach of the network. These techniques are especially effective with always-connected devices such as cell phones (Davis et al., 2005).

Once sensed, location can be used as an index to other elements of context. PhotoCompass (Naaman, Harada, Wang, Garcia-Molina, & Paepcke, 2004; Naaman, Song, Paepcke, & Garcia-Molina, 2004) generates meaningful event and location hierarchies based on timestamp and location data embedded in digital photographs. An even more detailed picture of physical context can be constructed by connecting to Web-based data sources. For example, the amount of daylight and the weather conditions when a photo was taken can be found by calling a Web service that has access to detailed logs of daylight and weather from around the world (Naaman, Harada et al., 2004). Items captured at a various locations can also be mapped by connecting to online Geographic Information System (GIS) data sources (Gemmell et al., 2006; Yeh et al., 2006).

SOCIAL

Social context includes other people with whom the user is engaged in some way (Bradley & Dunlop, 2005). Like "task," sociality is highly subjective. One may be near a person without being socially engaged, and the intensity of social interaction ranges from incidental to intimate. For example, two people sitting next to each other in a café (and thus in range of a Bluetooth signal) might be longtime friends, classmates who had just met during a class review session, professional colleagues, or complete strangers. Inferring a meaningful social relationship based on a simple sensor such as proximity is clearly difficult.

Nevertheless, because social interaction is important to many activities, it is often desirable to detect other people with whom one is interacting. Systems can perform this type of detection when the people involved are using devices that can connect in some way. For example, cell phones and PC's that are in close proximity can detect each other and connect via Bluetooth. Making this network connection useful then depends on applications that exploit it. MMM2, for example, senses nearby phones with Bluetooth and allows users to quickly share cameraphone pictures with others who are nearby (Davis et al., 2005). Since, as noted above, proximity does not imply a meaningful relationship, these applications must robustly handle a range of social interactions. The "context" of sending pictures is substantially different for a casual acquaintance as compared to a close friend or a business colleague.

TEMPORAL

Temporal context includes the present time, as well as the influence of past activities, and anticipated future activities (Bradley & Dunlop, 2005). Perhaps the most commonly-captured element of context is the current time. Timestamps are pervasive on PC's and other devices, easy to record, and useful. Organizing captured items by time is a logical and effective approach, although more complex processing is often needed to create meaningful temporal groupings (Naaman, Song et al., 2004). A large challenge is effectively capturing and exploiting temporal context over longer periods of time—that is, "history." Chalmers (2004) argues that users' contextual and interaction history is generally not exploited effectively in current systems. For example, context-sensing systems should able to monitor what types of contexts a user habitually enters, and optimize the information architecture and user interface to support interaction within these contexts. Developing approaches for sensing and using patterns of context over time is an open challenge.

Summary

Numerous approaches for detecting various elements of context have been proposed and implemented. These sensor-based approaches are seen to be particularly valuable for CARPE systems, as they help to make the vast quantity of captured data accessible and useful (Aizawa et al., 2004; Hori & Aizawa, 2003). Context-aware systems also have the potential to simplify many common PIM tasks, such as managing personal photos (Naaman, Song et al., 2004; Naaman, Yeh, Garcia-Molina, & Paepcke, 2005). However, while the idea of context is often discussed in PIM research (Barreau, 1995; Bergman et al., 2003; Kwasnik, 1989; Ravasio et al., 2004), most PIM system development has focused on indexing and organizing, rather than detecting and using context. UNC's Context Awareness Framework, based on the SOUPA ontology[1], is an attempt to create structured representations of context for a campus environment (Barreau et al., 2006). The research reported on here investigates ways of using these context representations to support students' PIM needs.

2.2.7 Conclusion

The purpose of this section was to assess the technical infrastructure available to support key PIM tasks: *refinding, reminding and task management*, *order-making*, and *reflection and metacognition*. These tasks were reviewed with the tasks motivating CARPE system design (Czerwinski et al., 2006). A broad range

[1] See http://pervasive.semanticweb.org/soupa-2004-06.html .

of technical capabilities—including capture, indexing, semantic association and layering, and context sensing—support PIM and CARPE functionality. In general, it appears that performance limitations are no longer the primary constraint on PIM system development. Current desktop systems can instantaneously query full-text indexes of a user's entire personal collection, and run complex monitoring and layering applications without degrading the performance of other software.

A primary challenge, then, is to create data models that support interfaces that are efficient and effective for users. Connected to this challenge is the need to investigate where the capabilities PIM and CARPE systems intersect, and can be combined into more powerful approaches for supporting users. For example, despite multiple implementations of different approaches to unifying users' files, no implementation has gained widespread acceptance, and most users still deal with information fragmentation as a daily issue. Current systems (such as MyLifeBits) are highly flexible and extensible, offering the potential to go beyond previous approaches, but these still must support users' tasks if they are to be adopted. The challenge is to integrate system capabilities and interfaces in new ways to offer better solutions to users' PIM needs. This HCI challenge is discussed further in section 2.4, "HCI support for PIM." The design research presented here seeks to exploit these technical capabilities to better support students' needs. In particular, this research explores how companioning context-sensing and PIM systems can simplify lower-order tasks (refinding; reminding and task management) and augment higher-order tasks (making order; reflection and metacognition).

2.3 Metadata in PIM

2.3.1 Introduction

Metadata supports the main PIM tasks identified in previous PIM and HCI research (see section 2.1, "PIM behaviors and practices," for detailed discussion of the user practices and behaviors underlying these tasks). According to Hert (2004), "metadata is information preserved in some artifact that performs the task of providing context designed to help users locate and understand the underlying data." Greenberg defines metadata more broadly as "data attributes that describe, provide context, indicate the quality, or document other object (or data) characteristics" (2004), p. 20. Another insightful description is presented by Green & Kent (1989):

> [metadata should] offer a selection of information relevant for a certain goal, and present it in a format appropriate for meeting this goal in a specific context. These varying manifestations of metadata

> should… exist within a coherent or consistent production model that follows the data throughout its life cycle (p. 29).

All of these definitions indicate that metadata is used to support some combination of user or system tasks and goals. Metadata research has examined numerous user tasks and system functions, including discovery, assessment, understanding, integration, archiving, and preservation (1995).

In contrast, the scope of this research is PIM systems, particularly for students. Table 6 presents four key tasks have been identified for these systems to support.

Table 6. User tasks for PIM system support.

PIM There are four main tasks that PIM can support (see section 2.1, "PIM behaviors and practices," for detailed discussion of these tasks and supporting references):
Refinding. Accessing information that one has acquired and stored in a PIM system (such as an email to a colleague, a report downloaded from a Web site, or a picture from a friend's wedding).
Reminding and task management. Keeping track of what projects and tasks one needs to work on, including key deadlines.
Making order. Filing or organizing as practices that help make sense of a complex stream of incoming data.
Reflection and metacognition. Improving metacognition, the "activities and skills related to planning, monitoring, evaluating, and repairing performance" (2005), p.148. Reflecting on one's activities to understand them more

deeply, and construct personal narratives.

These tasks are somewhat different than the information discovery, retrieval, and understanding tasks often discussed in relation to metadata. Metadata still has a key role to play in how PIM systems support these tasks. For example, Cutrell, Dumais, & Teevan (2004) argue that "support [in PIM systems] for rich metadata (such as people, time, task contexts, and events) is critical for finding information users have previously encountered" (p. 59).

In this section, metadata is considered as component of the overall *information architecture* (IA) of PIM systems. IA encompasses the organization of information, the labels used to refer to groups of content, the navigation framework, and supporting retrieval systems (2003). Within the IA, metadata serves as the "glue" between user needs and system support. That is, metadata enables the system to store and represent "data attributes" that are valuable to users when undertaking PIM tasks. To further illustrate this connection, Table 7 provides an example of metadata for each major PIM task. This table presents a synthesis of metadata for PIM use, based on my review of relevant literature and PIM systems.

Table 7. Example metadata for PIM tasks.

Lifecycle phase	Task	Example user need	Example characteristics	Example metadata properties
Creation	Making order	Place a reference suggested by a colleague in a location where it can be found again, and is meaningfully related to other materials.	*Topic* – associate the article with a general topic one follows *Contact* – associate the article with the colleague who suggested it	Free-text tags to describe topic; Standardized hierarchy of topics for a particular domain Contact inferred from email client
Searching	Refinding	Access a report downloaded from a Web site last month.	*Time* – restrict search to documents entered into PIM system last month *Project* – find the report via metadata associating it with a project, such as "Annual Performance Review"	Standardized date and time, e.g. ISO 8601 User-defined controlled vocabulary of projects
Utilization	Reminding and task management	Determine deadline for an upcoming conference presentation.	*Priority* – compare the importance of this deadline to other tasks *Project* – find the deadline via metadata associating it with a project, such as "XYZ Conference Panel"	Standard controlled vocabulary of priorities (e.g. Critical/ High/Medium/Low)
	Reflection and metacognition	Write a daily journal entry.	*Goal* – associate the journal entry with a particular goal one is pursuing, such as weight loss	User-defined controlled vocabulary of projects Social tagging of goals (e.g., 43things.com, JoesGoals.com)

Research into metadata in PIM is needed to support the design of effective and usable PIM systems. Key challenges for PIM metadata research include:

- *Identifying metadata elements that support users' PIM tasks.* For example, *time* and *project* metadata can support reminding, enabling users to keep track of ongoing tasks and deadlines.
- *Determining how these various elements should be structured and prioritized to support users' PIM needs.* For example, observation of students might show that they often refer to "activity" and "location" when discussing class materials in the Memex, but rarely refer to "time." Based on this finding, the IA would be designed to emphasize activity and location.
- *Supporting efficient and effective metadata creation in PIM systems.* For example, machine learning techniques can automatically generate some types of metadata. In addition, interfaces can be designed to support efficient manual metadata creation.

The following sections discuss these challenges in the context of an metadata lifecycle.

2.3.2 Lifecycles and the PIM context

PIM systems create, manage, and represent metadata. In order to study these functions in an integrated, coherent way, it is valuable to consider them from the perspective of an *information lifecycle* (see Figure 3). The information lifecycle is one model of information and metadata use in an organization (Green & Kent, 2002). It emphasizes that information activities take place in concert, not isolation. Information cannot be retrieved or used unless it has been authored and indexed in some way. Moreover, information changes through use. A document that has been indexed and classified is different (and presumably more valuable) than one that has not. More subtly, information changes simply by being retrieved and used, as it is incorporated into individuals' own knowledge networks, and then diffused through social connections. While designed for personal, rather than organizational, use, PIM systems incorporate many elements of the information life cycle. So this model serves as one lens through which to view and analyze PIM systems.

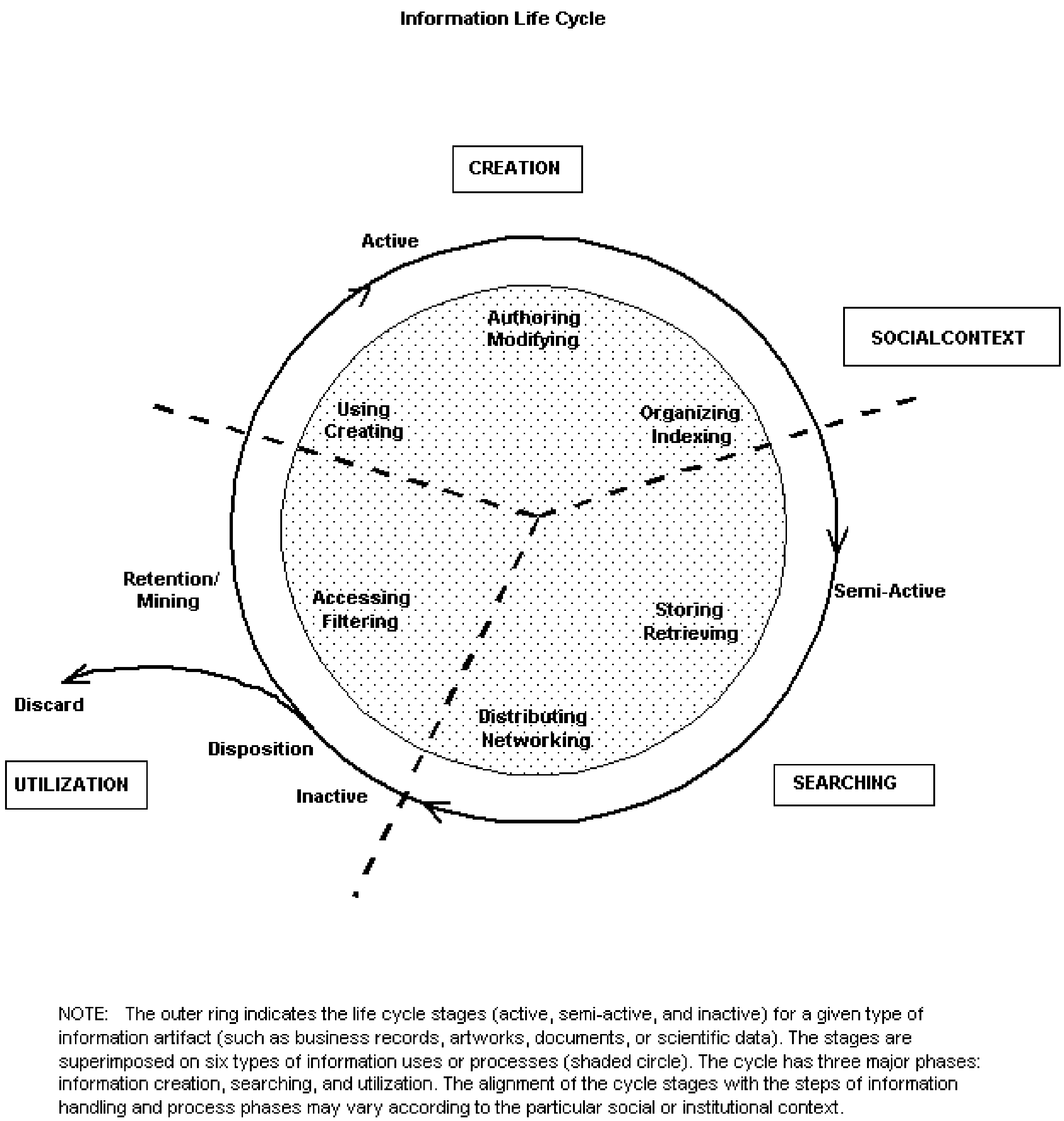


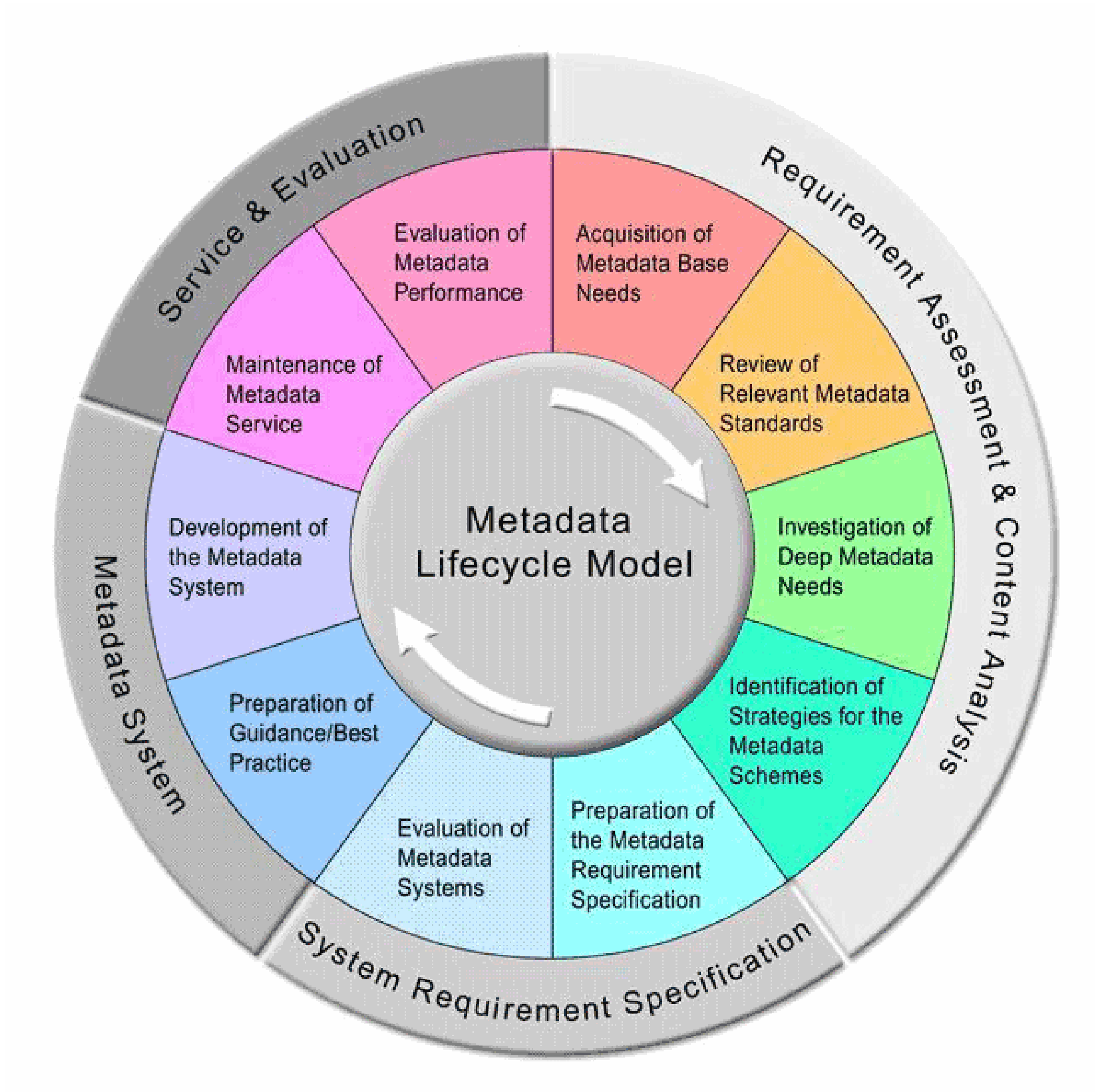
Figure 3. Diagram of information lifecycle
(from http://is.gseis.ucla.edu/research/dl/UCLA_DL_model.gif).

In particular, the information lifecycle provides a perspective for analyzing PIM metadata capabilities. It identifies *creation*, *searching*, and *utilization* as general phases of metadata management. These phases are closely related to the four key PIM tasks identified previously. Creation is related to making order; searching is related to refinding and reminding; utilization is related to task management, reflection, and metacognition. In addition, the information lifecycle identifies *social context* as a general component of information management. This component relates to the use of contextual metadata in PIM, although in this research contextual metadata has a broader focus than only *social* context.

The information lifecycle presents basic phases of information management from a high-level perspective that can inform system modeling and design. This cycle of activity emphasizes that all aspects of PIM—including creation, searching, and utilization—are important, which encourages holistic design. Table 7, "Example metadata for PIM tasks," presents the four key PIM tasks discussed in this research in relation to the information lifecycle.

Researchers have developed more specific lifecycle models focused on metadata development. Figure 4 presents an overview of one metadata lifecycle model (Chen & Chen, 2005).

Figure 4. Metadata lifecycle model (http://www.sinica.edu.tw/~metadata/design/lifecycle_eng.htm).



In this model, developing and implementing metadata involves four major phases:

1. Requirement Assessment & Content Analysis
2. System Requirement Specification
3. Metadata System development
4. Service & Evaluation

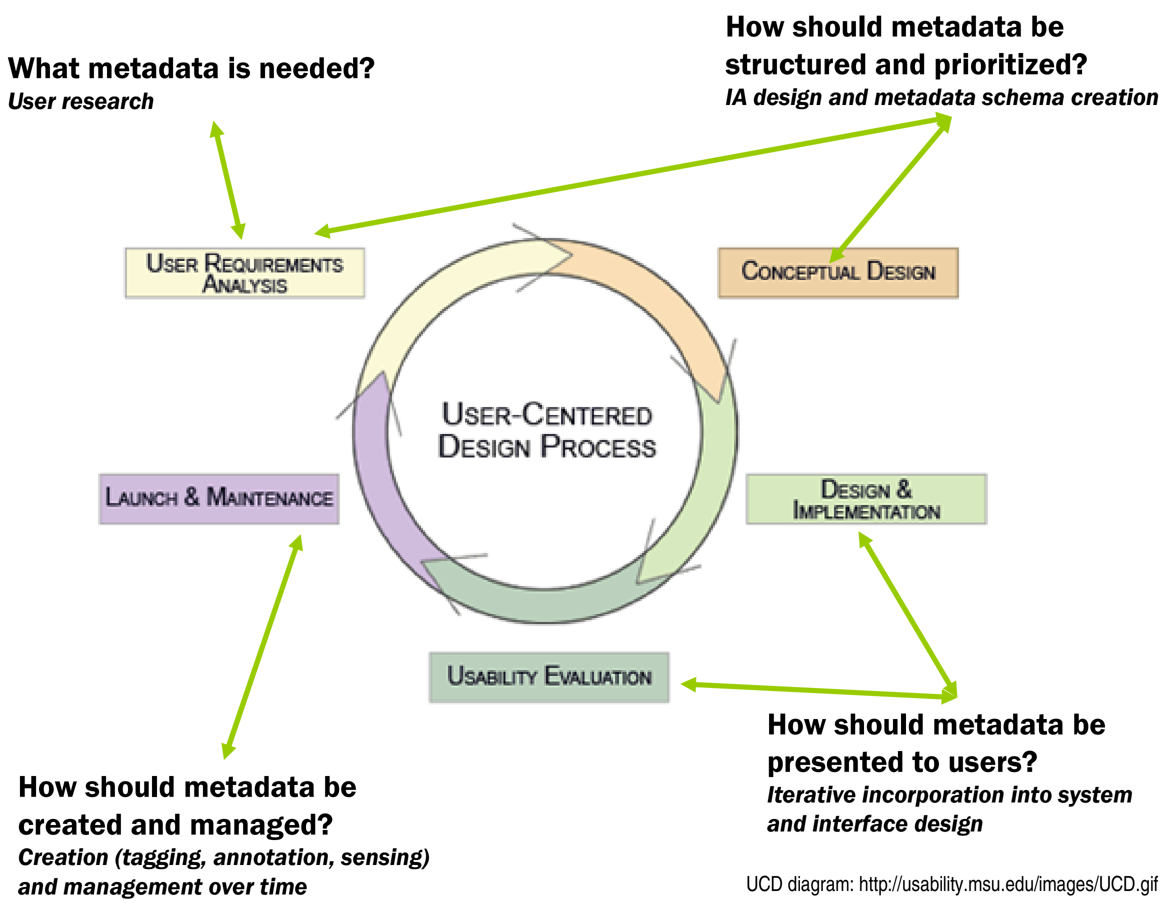
This lifecycle can be compared to a user-centered design (UCD) lifecycle (Courage & Baxter, 2005; Duyne, Landay, & Hong, 2003; McClelland & Suri, 2005). A user-centered design typically has three main phases. Table 8 presents these phases and their application to metadata development. Overall, it appears the metadata lifecycle and the user-centered design lifecycle are closely related. The goal of this research was to apply a user-centered perspective to the design of PIM systems. I therefore discuss metadata development activities using an explicitly user-centered model. Figure 5 presents a graphical overview of a user-centered design model linked to metadata development.

Table 8. Application of UCD lifecycle to metadata development.

Phase in UCD lifecycle	Application to metadata development
User research and task analysis User research (including fieldwork, surveys, etc.) enables the understanding of users' goals, which can be further analyzed in terms of specific tasks and system requirements.	In this process, the initial focus is on users' needs and how they can be supported. This focus is equally applicable when developing metadata: "[before undertaking design] it seems clear that we should first understand what metadata elements are important or useful to users" (Lan, 2002), p. 13.
Conceptual design, prototyping, and formative evaluation User research can support an iterative design process, in which design concepts and prototypes are created, and then evaluated by both designers and representative users. The evaluation identifies problems with and opportunities for improving the design.	The user research and task analysis informs the design of the overall information architecture (including organization, labeling, navigation, and search systems). Specific metadata schemas can then be designed to support the IA. The metadata is then incorporated into system infrastructure, such as a search engine, and user interfaces. The prototype system and interfaces are then evaluated with users through usability testing.
Implementation and summative evaluation Ultimately, prototypes are refined into forms that can be regularly used. As people use the system in practice, further opportunities for design emerge. Comprehensive assessment of the strengths and weaknesses of the design can be created through summative evaluations such as formal usability testing, benchmarking, and	Once the metadata is structured and evaluated with users, it is implemented with a working system. Processes for metadata creation and maintenance (such as manual tagging and annotation, or algorithms) being functioning, making metadata available to users.

surveys of users.	

Figure 5. User-centered design process in relation to metadata development.



One key distinction between the metadata lifecycle and the user-centered design lifecycle is that the user-centered model emphasizes *usability evaluation*, whereas the metadata lifecycle refers to evaluation generally. This focus on usability evaluation is related to the user-centered design lifecycle's focus on designing representations, including user interfaces. By contrast, the metadata lifecycle concentrates "under the hood" on metadata requirements and system support. In addition, the user-centered design process emphasizes *iterative user feedback and design*, in which prototype designs are tested with users and then revised based on the users' feedback.

The goal of this research was to apply a user-centered perspective to the design of PIM systems. I therefore discuss metadata development activities using an explicitly user-centered model. The following subsections discuss each of the three phases of the user-centered design lifecycle—user research, conceptual design, and implementation—in relation to metadata development.

User research

The purpose of user research is to:

> find out who the people are, what they do now, and what the new system is expected to do for them... It is important to spend some time watching users do their jobs with their current tools, whatever they may be. The closer you are to the prospective users and the more you know about them, the more likely you are to produce a system that meets their needs (Rubinstein & Hersh, 1984).

User research entails developing a deep understanding of people in a particular domain—their practices, culture, and so forth. In contrast to general social scientific research, which seeks to build theories and models of individual and group behavior, user research seeks to understand behavior in order to support design.

In the scope of this review, the goal is to determine "what metadata elements are important or useful to users" (Lan, 2002), p. 13. Research has addressed this question by examining which document *criteria* users rely on to assess whether a document or information object will be relevant and pertinent to their needs. Theorists have classified types of metadata by whether they relate to *content*, *structure* or *context* of information (Cox, 2001; Gilliland-Swetland, 2000; Greenberg, Crystal et al., 2006). This dissertation focuses on contextual metadata, rather than content or structural metadata. My emphasis on contextual metadata reflects the salience of context for PIM tasks, and the need for more in-depth field research on how people use context in PIM activities.

The following two subsections review research first on relevance criteria, and then on people's use of context. The aim is to draw insights from these studies that can inform the design of metadata schemas for PIM systems.

Relevance Criteria and Metadata

Much research in information retrieval has examined the criteria people use to assess the relevance of documents (see Mizzaro (1997) and Borlund (2003) for reviews). Relevance criteria are important for system design because they can be used to inform the choice and representation of metadata elements. For example, an empirical finding that users often refer to the publication date of articles could motivate designers to include publication date as a metadata element in an IR system and display it in surrogates. An example of this approach is Hufford's (1991) study of reference librarians at major university libraries, using both card catalogs and OPACs. He counted the number of times specific elements were used and found that seven elements accounted for 90.7% of total uses. Based on these results, he argued that OPACs should have minimal surrogates with a limited number of elements.

Barry (1994) had students and faculty from various disciplines (e.g., history, English) examine both surrogates and documents from a mediated online search related to a current information need. Participants worked with hard copies, and were asked to circle any part of the document that would lead them to pursue it. This technique of directly eliciting relevance criteria from end users proved effective and has motivated much subsequent research. Barry's taxonomy of relevance criteria included 23 categories, such as "depth/scope," "affectiveness," and "tangibility." The three most important criteria were depth/scope, content novelty, and accuracy/validity. These categories were combined into seven larger groups, such as "criteria pertaining to user's belief and preferences." The results show the wide range of "beyond topical" criteria that users consider when evaluating documents.

Numerous subsequent studies (see, for example, Bateman, 1998; Barry & Schamber, 1998) using a variety of methods have identified additional criteria beyond those in Barry's study. Lan (2002) studied graduate students searching for research related to their dissertations. Analyzing highlighted regions in the documents, he found users employed a wide range of document characteristics. Lan (2002) emphasized the importance of characteristics that enable users to filter or reconsider documents when topicality alone is insufficient. Tombros, Ruthven, & Jose (2005) asked "what features make a Web document useful for information seeking?" and conducted a think-aloud study to discover what features users identified as useful to their searches. They identified an array of structural features, such as layout, links, and images, that users relied on when assessing the relevance and usefulness of Web pages.

Overall, relevance research has focused on how people assess documents in the context of information seeking and retrieval—indeed, the most current review of the research is titled "The concept of relevance in IR" (Borlund, 2003). PIM is clearly a different domain than IR. In general, relevance criteria identified in IR studies seem to have limited applicability to PIM system design. As discussed previously, information seeking is only one component of PIM behavior. Moreover, PIM users are engaged in *refinding* information they have already stored and indexed in some way, rather than seeking new information from a source such as a database.

The main contribution relevance criteria research makes to PIM is methodological. Recent research has focused on finding more effective ways to elicit relevance criteria and judgments from users (Crystal & Greenberg, 2006; Rieh, 2002; P. Tang & Solomon, 2001). These studies have combined video captures of user activity with interviews, questionnaires, and content analysis to develop richer models of relevance behavior. User research for PIM metadata can draw on these methodological advances. In addition, user research for PIM metadata can draw on the criteria (and classifications of criteria) reported in IR relevance studies to provide a foundation for analyses of relevance criteria in PIM. However, it should not be expected that there will necessarily be a strong similarity between criteria in IR and in PIM. Furthermore, user research in PIM should not be restricted to the information seeking/retrieval context, because PIM encompasses a broad range of activities, goals, and tasks.

CONTEXT

According to Barreau (1995), "Context is the situation in which an event occurs. Context includes all aspects of a person's experience, and it has long been recognized as a factor in human behavior." Dey, Abowd, & Salber (2001) define context as "any information that can be used to characterise the situation of entities… typically the location, identity and state of people, groups, and computational and physical objects" (p. 100). Bradley & Dunlop (2005) examined definitions of context in computer science, linguistics, and psychology, and identified four primary components of context:

- Task context
- Physical context
- Social context
- Temporal context

In addition, they identified two further components of context: *cognitive* (i.e., subjective context) and *application/system* (i.e., technical context).

These definitions have informed my understanding of context in PIM systems. Within this scope, "context" appears to mean *the aspects of a person's situation and experience that can be systematically captured and represented.* Some researchers have argued against this general perspective on context. Both Chalmers (2004) and Dourish (2004) have criticized computer science research on context awareness. Dourish notes that conventional definitions of context assume that it is:

- a form of information that can be encoded/represented
- delineable
- stable

- separable from the underlying activity

He questions all of these assumptions. On his view, context is not clearly delineable or separable from the underlying activity. Rather, context is constructed and negotiated as part of activities. Therefore, context generally cannot be easily encoded or represented. Dourish argues that designers should eschew the “use of predefined context within a… system” (p.26). Instead, they should pursue ways for systems to “support the process by which context is continually manifest, defined, negotiated and shared?" (p.26). That is, “the meaningfulness of artefacts arises out of their use within systems of practice” (p. 28). This is not to say that context sensing is useless, but that researchers need to attend to how people really construct and use context in practice. Thus, while these criticisms merit consideration, the focus of this dissertation is on developing structured representations of context based on users’ needs. It is anticipated that grounding context sensing in user research will lead to designs that are useful and usable, even if the representations of context are limited.

Some field research has directly investigated the role of context in PIM, and the findings from these studies can inform the design of metadata for PIM. Kwasnik (1989) examined how university faculty organized documents in their offices. She coded documents into seven groups representing different criteria the participants used for classifying documents. Four of these groups are related to context as discussed in this dissertation: “situation attributes, ” “time,” “value” and “cognitive state.” These groups were found to account for a large proportion of participants’ classifications. This study laid the foundation for research on context in PIM, as it was one of the first to argue that “in designing systems for organizing materials, it might be advantageous to incorporate information about contextual variables, such as use, since these seem to be particularly important in classification decisions made within personal environments” (p. 207).

Barreau (1995) took a similar perspective, but examined electronic file systems. She also identified a number of contextual criteria used by participants to classify documents. These included:

- use, e.g. ‘hot’ projects
- currency/recency
- habit/procedure
- anticipated need/access
- importance/value

One limitation of these studies is they are now somewhat dated. In a more recent study, Henderson (2005) examined the personal folder structures of participants using a logging tool, then coded the folders for the classification criteria they represented. The key criteria identified were *genre*, *task*, *topic*, and *time*—of these, task and time can be considered contextual criteria. Bruce, Jones, & Dumais (2004) conducted a survey of PIM users and concluded that task context is one of the key requirements for PIM systems. Bergman, Beyth-Marom, & Nachmias (2003) made a similar argument, but emphasized that users' should be able to view items in the context of other, related items. For example, if a student was typing a document while viewing a PowerPoint deck, she should later be able to retrieve the two documents together.

In addition to these studies of context in document classification and use, another line of research has examined the criteria that users identify for multimedia objects, such as personal photographs (Naaman, Harada et al., 2004). Naaman et al (2004) asked participants to refind personal photographs using contextual metadata, such as "time of day" and "weather." Results showed that participants relied on several metadata elements to find the photographs. While useful, the results from this study are limited. Participants only searched for three photographs each, and the task and procedure were artificial.

As this study indicates, raw date and time metadata may be of limited value, as users' often prefer to think of their personal collections in terms of meaningful demarcations like "season." It is easier to remember that a picture was taken last spring, than that it was taken on April 10th. Petras, Larson, & Buckland (2006) made a similar argument in developing "Time Period Directories." Time Period

Directories connect named time periods (e.g., The Renaissance) or events (e.g., the French Revolution) with their associated dates or date ranges and locations. These directories enable users to “explore the historical context and interconnections of people, topics, location, and events” (p. 152).

While Petras et al (2006) focused on retrieving historical information through digital libraries, having meaningful periods, events, and locations is important to PIM as well (Naaman, Song et al., 2004). For example, Ringel, Cutrell, Dumais, & Horvitz (2003) developed a timeline-based presentation of search results. The visualization contained “landmarks,” including both public (news, holidays) and personal (appointments, photos) landmark events. A usability study of the visualization showed that adding these landmarks help people complete information-seeking tasks faster. This result shows how including personally meaningful events, such as holidays and appointments, in PIM metadata, can be valuable.

Overall, user research that can ground the design of contextual metadata for PIM is still limited. Bradley and Dunlop (2005) specifically note that “further exploration is required in… which aspects of task, social, physical, temporal and cognitive aspects of context are relevant to users” (p. 441). This need for further exploration motivates my research plan, which focuses on developing contextual metadata based on fieldwork with undergraduate students. The following subsections review research on the remainder of the metadata lifecycle: developing metadata schemas for PIM systems, and creating metadata in PIM.

IA and Metadata schemas for PIM

As discussed previously, metadata is a component of the information architecture for a system. Developing a metadata schema for a system is therefore part of developing the IA for the system. Researchers have outlined overarching IA design processes; metadata design can be seen as one part of such a process. Brinck et al.'s (2002) IA process specifies that information architects should "Create and evaluate the core structure of the IA." This phase encompasses developing and applying metadata (Brinck et al., 2002).

The "core structure" of the IA is often described using *faceted metadata* (Crystal, 2007; Yee, Swearingen, Li, & Hearst, 2003). Yee et al. (2003) define facets as "orthogonal sets of categories." They note that facets may be either *flat* (containing a single level of values) or *hierarchical* (containing multiple levels of values in an ancestor-descendant structure). Furthermore, facets may be *single-valued* (allowing just one value to be assigned to an item), or *multi-valued* (allowing more than one value to be assigned to an item).

Faceted metadata is also well-suited to the dynamic and situational nature of PIM. As Kwasnik (1999) notes, "The notion of facets rests on the belief that there is more than one way to view the world, and that even those classifications that are viewed as stable are in fact provisional and dynamic" (p. 25). Kwasnik (1999) also outlines a process for designing facets:

1. **Choose facets.** Decide on the important criteria for describing resources, based on user research.

2. **Develop facets.** Develop and expand each facet using its own logic and warrant and its own classificatory structure. For example, when classifying fine arts images, a *Period* facet could use a timeline structure, a *Materials* facet could use a hierarchical structure, and a *Place* facet could use a part/whole tree structure.

3. **Analyze entities (i.e., resources) using the facets.** For example, in classifying a document about "Masters paper requirements," the facets *Audience* and *Popularity* could be examined. The documents' audience might include "Masters students" and "Faculty." Popularity would be assigned by the system during use.

4. **Develop citation order.** Determine how facets are prioritized, and how resources will be ranked or ordered by the system.

This process can be applied to develop metadata for PIM systems. The information architect first defines facets, and then specifies metadata elements in a *schema*. A schema "establishes and defines data elements and the rules governing the use of data elements to describe a resource" (J. Johnson & Kniesner, 2003). For example, a "Date accessed" attribute might be represented by a "Date accessed" metadata element. This element would be encoded using a standard format, such as the Dublin Core's *Date* element and the ISO 8601 profile (http://www.w3.org/TR/NOTE-datetime). Elements can then be further refined using qualifiers, which specify more precise aspects of the element. For example, *Date* could be qualified as *Date Modified* and *Date Created*.

Metadata schemas have been developed for many domains. For example, The Alexandria Digital Library Project developed an extensive metadata schema for geographically-referenced information (Frew et al., 1996). Wang, Wang, Luo, Wang, & Xu (2004) presented a schema for integrating scientific data in a grid computing environment. The Food and Agriculture Organization of the United Nations has published numerous metadata schemas for describing information related to food and agriculture production and management (FAO, 2006).

Despite the extensive work on creating and implementing metadata schemas for digital libraries and related area, little attention has been given to schemas designed specifically for PIM applications. One reason for this difference may be that the Web's open and decentralized structure makes it feasible to create metadata for Web applications, such as digital libraries. In contrast, PIM tasks are often conducted using proprietary applications such as Microsoft Windows and Office that are more difficult to modify and extend.

Some recent research has begun to explore metadata schemas designed specifically for PIM systems. Nejdl's work on the Beagle desktop search engine led to the development of metadata to represent *email context*, *browsing context*, and *publication context* (Chirita, Gavriloaie, Ghita, Nejdl, & Paiu, 2005; Nejdl & Paiu, 2005). This metadata was designed to support refinding tasks, particularly in a research context. Liu, Yang, & Vemuri (2005) focused on the MyLifeBits/SenseCam system, and developed a "minimal event schema" to support veterinary students (see Figure 6).

Figure 6. Minimal event schema for Memex system (Liu et al, 2005).

- *Person (Name, Email, Address, Designation)*
- *General Event (*Participants, Timestamp, Association, * General Stream)*
- *General Stream (Accessed time, Modified time, Created. Time, Author, title, Content)*
- *Email Event (*From, *To,*CC,*BCC, Timestamp, Association, Content)*
- *Sensory Event (*Participants, Timestamp, Environment)*
- *Environment (*Location, *Audio,*Picture,* Cognitive state)*
- *Location (GPS, user annotation)*
- *Audio (feature vectors of audio)*
- *Picture (feature vectors of picture)*
- *Cognitive state(Sensors information)*
- *Participants([Person]+)*
- *Address(Street, Apt Number, City, Zip Code)*

Greenberg et al. (2006) also focused on Memex system. They developed a metadata framework to support undergraduate biology students (see Figure 7).

Figure 7. Document and event metadata for Memex system (Greenberg et al., 2006).

Key

Generation methods
A = Automatically generated
D = Derived
H = Harvested
M = Manually generated

Requirement
R = Required
O = Optional metadata
*The R/O designation only refers to manually generated metadata

Document Metadata			
Element Name	**Description**	**Example**	***Code***
Name/Title:	Short label/description of data type.	Gymnosperm Identification	*A or M, R*
Description:	Longer description of data type.	This purpose of this lab is to collect and identify various gymnosperm species that reside in Coker Arboretum.	*M*
Assigned Date	The date the data type is assigned by instructor.	mm-dd-yyyy	*A*
Due Date	The date the data type is due to the instructor.	mm-dd-yyyy	*M, R*
Due Time	Describes the specific time of day that the data type is due to the instructor	hh:mm a.m/p.m.	*M*
Group	Lists members	* Members	*M*

Members	of class who are working together on data type, if any.	are tagged to assignment using links to their profiles in a user database.	
Grade	Numerical evaluation of data type.	0-100	*M*
Percent of total grade	*The weight of data type on total class grade*	*20%, 40%*	*M*
Object collector/ owner	Name of person who will store memory in MLB	Doe, Jane	*D*
Class Dept. Code	Four letter department code	BIOL, INLS	*M/R*
Class Number	Three digit class number	096, 156, 157	*M/R*
Class Section	Two digit code	01	*A*
Class Name	Course name	Local Flora	*A*
Professor	Last name and first name combination.	Smith, Paul	*A*
Scope Note	Automatic summary or keywords	Fieldtrip report from the arboretum tour (Automaticall y extracted from document text)	*A,D, + H*
Annotation	Field used by student at their discretion.	Focus of fieldtrip was gymnosperm s	*M/0*
Starred Item	Designates an implied importance to the content	Binary value: Star or no star.	*M/0*
Location	Location	Derived	*A*

	where data type was created.	using GPS of RFID	

Event Metadata			
Element Name	**Description**	**Example**	***Code***
Name/Title	Short label/description of data type.	Plant reproduction	M, R
Date recorded, timestamp	Timestamp data type was recorded /created.	Sat Jul 23 02:16:57 2005	A, R
Format	*Data type file association*	*Mp3, Mpeg, etc.*	A, R

These approaches provide a foundation for future research on metadata schemas for PIM systems. The main limitations of these schemas are that they are not based on extensive user research, and have not been evaluated in practice. Therefore, it is unclear how well these metadata will support users' tasks. In addition, these schemas as largely focused on refinding tasks, with less attention given higher-order tasks such as reflection and metacognition. The M^2 framework begins to address this issue by examining how context could support memory and learning in education. Overall, the research conducted for this dissertation extends previous research on metadata schemas for PIM by emphasizing a user-centered metadata design process. Ethnographic fieldwork was conducted to identify user needs and tasks, and recommendations for PIM metadata and system design were developed based on these needs.

Metadata creation in PIM

Once a metadata schema is defined, metadata must be created. Metadata creation has proven to be a significant challenge for Web-based collections, such as digital libraries. The traditional creators of metadata, librarians and indexers, are professionals with specialized expertise. It is difficult for specialized professionals keep pace with the explosive growth of Web-based collections, leading some researchers to characterize metadata creation as "bottleneck" for digital libraries (Liddy, 2002). Research has begun to address this bottleneck by exploring improved methods for creating metadata, both manually and automatically (Greenberg, Crystal, Robertson, & Leadem, 2003; Greenberg, Spurgin, & Crystal, 2006; Yilmazel, Finneran, & Liddy, 2004).

Metadata creation is also an important challenge for PIM research. If contextual metadata is to be incorporated into PIM user interfaces, methods are needed for efficiently and reliably creating that metadata. As with digital library systems, PIM systems can incorporate both automatic and manual metadata creation methods. Automatic metadata creation methods for PIM systems could include:

- Context-sensing technologies, such as GPS, light sensors, and so forth. These technologies are discussed in Section 2.2, "PIM and capture systems technology."
- Algorithms that map usage patterns in a PIM system to a metadata schema or ontology, e.g., (Chirita et al., 2005; Nejdl & Paiu, 2005).
- Machine learning techniques that can automatically classify or tag textual data based on statistical patterns, e.g. (Efron, Elsas, Marchionini, & Zhang, 2004).

Manual metadata creation is labor-intensive, but can be made more efficient with system support. Crystal (2003) identified three areas for support of manual metadata creation:

- *Integration* between information seeking or analysis, and metadata entry.
- *Filtering/flagging* of incomplete or potentially incorrect metadata.
- *Contextual information* related to how the metadata will be represented and used by the system, to motivate high-quality metadata creation.

Detailed investigation of metadata creation methods for PIM is not a primary goal of the research reported on here. Rather, this research focused on identifying metadata elements that are particularly critical to PIM users, in the educational environment.

2.3.3 Conclusion

The purpose of this section was to discuss the role of metadata in PIM systems, with a particular focus on contextual metadata (i.e., metadata that represents elements of a person's context). Metadata for PIM was examined from the perspective of user-centered design, encompassing user research, IA design, metadata schema development, and metadata creation. Review of research related to these phases of the design process indicated that there has been extensive research on relevance criteria for information retrieval, but an analogous research base for PIM is still being developed. In general, research has focused on supporting refinding; research on higher-order PIM activities such as making order and reflection/metacognition has been limited. Thus, an open area for research is developing metadata to support these activities.

There is also a great need for the *evaluation* of specific metadata schemas/frameworks in PIM use. For example, Cutrell et al. (2006) argue for importance of rich metadata, but the use of different types of metadata has not been evaluated with real PIM users, in the context of their actual work practices (Boardman, 2004). There is also limited research on metadata creation in PIM.

Field studies of real context-sensing, annotation, tagging, and related practices are needed to complement earlier studies on filing practices.

Overall, metadata is a key component of PIM systems, and more detailed research on PIM metadata is needed as PIM systems become more pervasive and sophisticated. The focus of this research is developing design directions for student-centered PIM systems that can support higher-order activities such as reflection. The research reported on here identifies metadata elements that can support these activities, and assess whether this metadata can be realistically created and managed as part of students' typical practices.

2.4 HCI Support for PIM

This section addresses the interaction styles and interfaces that have been developed to support PIM tasks, and summarizes the key user goals and needs for each of the main PIM tasks that have been identified in previous PIM and HCI research: refinding, reminding and task management, order-making, and reflection and metacognition. (The user practices underlying these needs and goals are discussed in detail in section 2.1, "PIM Behaviors and Practices"). I then discuss designs that have been developed to support these tasks and needs. For example, keyword search of personal files with associated filters has been developed to support refinding, and annotation of captured information objects has been developed to support sensemaking and refinding (the technical architectures underlying these interfaces are discussed in section 2.2, "PIM and capture systems technology").

I link the theoretical arguments for each type of task support to specific designs that have been described in the PIM, HCI and related research literature. Since there a vast number of systems that support some aspect of the tasks examined here, I have selected a subset of systems that provide particularly innovative, useful, or intriguing designs. In each subsection, I identify the missing links between user research and existing design approaches, and point to how my research illuminates possibilities for improved design that can address these gaps.

2.4.1 HCI Support for PIM Tasks

In these subsections, I summarize the key user goals and needs for each of the main PIM tasks that have been identified in previous PIM and HCI research: refinding, reminding and task management, order-making, and reflection and metacognition.

Refinding

Capra & Pérez-Quiñones (2005) contrast finding and refinding. Finding, typically referred to as "information seeking" (Bruce, 1998; Marchionini, 1995; Saracevic et al., 1988), involves looking some unknown information based on an information need that can range from tightly defined (e.g., find a particular fact) to vague and exploratory (e.g., find something "of interest" in a general area). Refinding involves looking for information that one has already seen—"getting back to the information" (Capra & Pérez-Quiñones, 2005) (p. 38).

User Needs

One of the most prominent results from empirical research on refinding is that browsing dominates searching in many situations (see Ravasio, Schär, & Krueger (2004) and detailed discussion in section 2.1). Research demonstrates that users want to see their files in the context of a personal collection, not just to instantly access a particular file or information object. Furthermore, users of modern desktop systems are often frustrated that their information is fragmented by application or file type (Bergman et al., 2003; Jones, Munat et al., 2005). For example, information used to prepare for a class presentation may be scattered across PowerPoint files, Word documents, emails, and Web pages (both local and remote). Bruce, Jones, & Dumais (2004) surveyed a range of users and identified four additional key user needs: ease of communicating personal information to others; ease of accessing information in multiple ways; ability to integrate new information or new references with ongoing projects and existing organizational schemes; persistence of information.

To summarize, then, research on refinding practices indicates that users need PIM systems that provide unified, flexible access to information of all types, in the context of a browsable and persistent personal collection. It should be easy to share information in this collection with others, and to integrate new information with the existing structure.

Approaches

One solution to the information fragmentation problem is to provide unified search across the entire personal file store by providing full-text search across all indexable file types. Stuff I've Seen (SIS) (Dumais et al., 2003) appears to be one of the first significant implementations of this approach. SIS provides a standard list of ranked surrogates (surrogates include a title, date, author, the first 300 bytes of a message or documents, and a thumbnail of an images or slides). Results can be ranked by an Okapi probabilistic relevance algorithm or by date. SIS also provides filters, enabling restriction of searches to a type of object (all/Web/Outlook/or a particular file type), or by date, author, rank, or contact (e.g., the recipient of an email). The UI design of SIS emphasized these filters, following the authors' argument that "because the information is personal and has been seen before, we believe that rich contextual cues such as time, author, thumbnails, and previews can be especially useful" (p. 73).

Empirical evaluation of SIS showed it was regularly used in practice, and that sorting results by date was generally preferred. The effectiveness of this type of unified desktop search is clear, and the technology has matured into commercial implementations such as MSN Desktop Search and Copernic Desktop Search, as well as refined research systems such as Phlat (Cutrell, Robbins et al., 2006), which also incorporates user tagging. Google Desktop also provides a similar implementation, though it places search results in a Web browser, rather than a dedicated UI.

The limitation of these approaches is they do not seem to fully address the issue of unified access across multiple file formats and applications. Users also want a browsable personal collection with a consistent structure (as opposed to search results which are dynamic and unpredictable). Indeed, in the primary SIS empirical study (Dumais et al., 2003), users retrieved objects from the system only four times per day on average. It seems safe to say that these knowledge workers at Microsoft were using considerably more than four information objects daily. Consistent with previous research using less-advanced desktop search systems (e.g., systems that can only match file names), search alone does not fully support users' refinding needs.

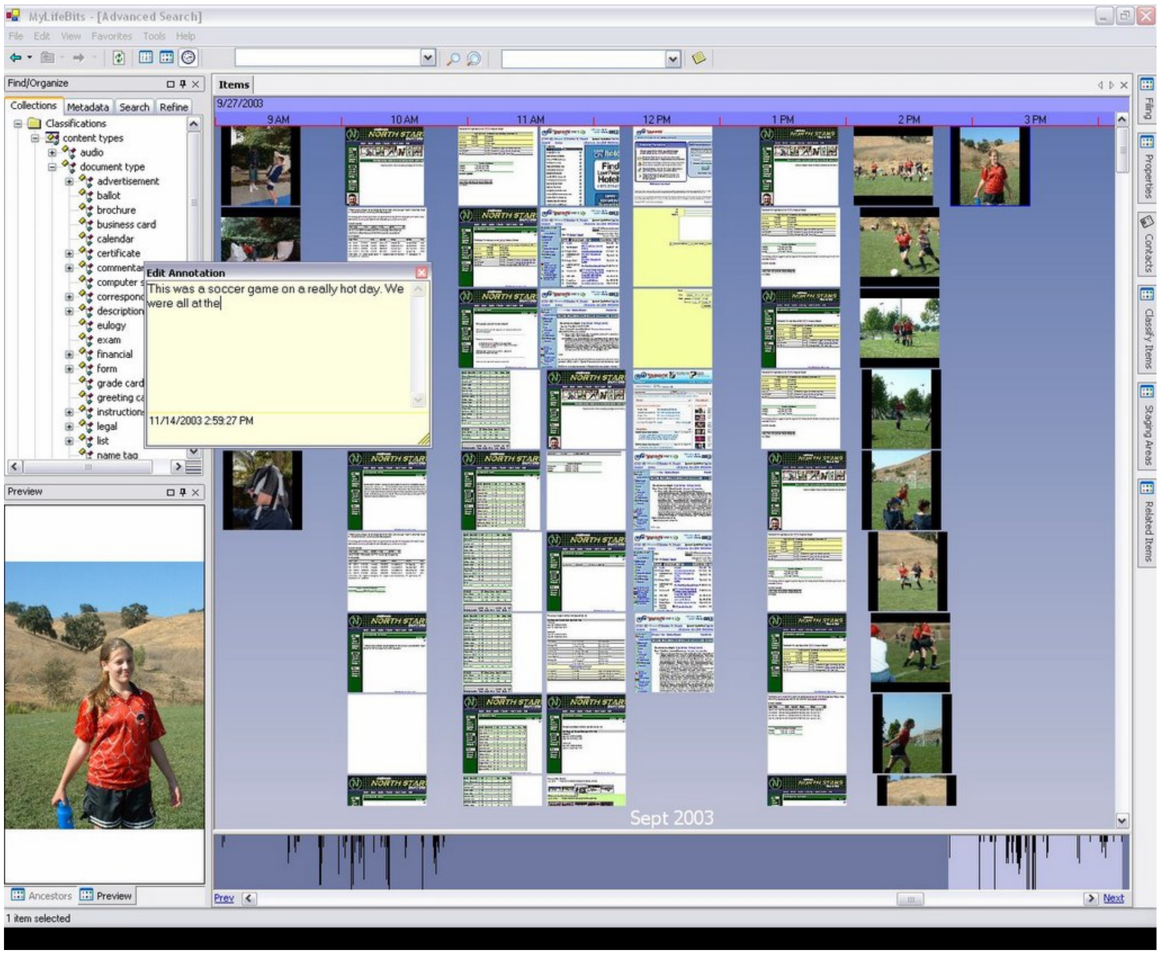


Figure 8. Screenshot of MyLifeBits.

MyLifeBits (see Figure 8) acknowledges the limitations of search by providing additional support for refinding through browsable views (Gemmell et al., 2006). A timeline view (of captured images, for example) allows users to quickly survey a large number of objects in a given time period. Users can also build their own collections, which can contain multiple file types. Thus MyLifeBits addresses users' needs for both unified search and persistent, browsable collections in a way that desktop search systems do not. However, the effectiveness of this approach has not been validated in practice, and it is unclear whether MyLifeBits has sufficient "management and indexing strategies to help people to efficiently deal with their massive histories" (Komlodi et al., 2007), p. 27. The technology probe component of this research provides insights into the extent of this problem in practice.

In addition, MyLifeBits does not directly address users' needs to easily share information and integrate new information into established structures. PICASSO (Guven et al., 2005) partly supports these user needs—it enables user tagging, and sharing captured items with colleagues on an intranet. One area that requires attention is the overhead (in terms of cognitive effort) required to develop and learn a new organizational scheme, whether develop by an individual or through social tagging. Users will need to learn how to browse these new schemes effectively, which might initially discourage their use.

Future research in refinding should continue to probe domain-specific practices to identify further possibilities for supporting user needs and building systems that are more closely bound with practice. For example, based on a study of academic users, Henderson (2005) has proposed extending desktop search with faceted access. Faceted search has proved effective for resource discovery within online collections (Yee et al., 2003; Zhang & Marchionini, 2005). However, the facets users implicitly rely on when developing personal folder structures—such as genre, task and topic (Henderson, 2005)—aren't represented in typical PIM systems. Incorporating such facets might improve refinding. An important open area for research, then, is developing metadata to represent these facets. Interfaces, such as faceted search interfaces, for exposing this metadata to users, should also be designed and evaluated. A further potential approach is integrating simple semantic tagging capabilities, particularly for multimedia (Richter et al., 2005).

Reminding and task management

Research shows that people manage their personal information to support their activities or tasks (Bergman et al., 2003; Boardman & Sasse, 2004; Jones, Munat et al., 2005). Thus, managing tasks is often as important as managing collections of information, particularly when one has a large number of complex tasks that extend over time. Users need to be reminded of tasks, particularly when they have associated deadlines.

USER NEEDS

Research on reminding and task management practices indicates that users need to organize and structure their projects. This type of freeform intellectual activity is often difficult for software to support effectively—for example, commercial PIM systems such as Microsoft Outlook provide only simple supports, such as lists of "tasks" (where a task is a text entry with some metadata). Users have adapted many tools to their task management needs. For example, field studies of folder usage on modern desktop systems show that "...re-access to personal information is not necessarily the sole or even the primary purpose of a folder organization... the folder structure for a project is frequently a problem decomposition" (Jones, Phuwanartnurak et al., 2005). In addition, the extensive use of paper in offices is attributed to paper's affordances, which better support reminding and task management than current digital alternatives (Bondarenko & Janssen, 2005).

To summarize, users need to identify projects, decompose them into manageable tasks, keep track of these tasks, and be reminded to work on them (and when they are due).

APPROACHES

Kirsh (2001) argues that users need three basic affordances to support task management and reminding: *entry points* (cues to start tasks, such as to-do lists), *action landscapes* (arrangements of items to support an activity, such as a folder full of documents related to a project), and *coordinating mechanisms* (support for action and collaboration across time and space, such as calendars). While all of these affordances have been developed in various forms, a large gap between intended use and actual practice often exists. Numerous field studies of email usage have demonstrated that modern knowledge workers rely on email as entry point, action landscape, and coordinating mechanism (Bellotti et al., 2003; Boardman & Sasse, 2004), while email clients are designed mainly to support quick communication.

Newer designs have attempted to bridge this gap by integrating task management and reminding into existing applications. Taskmaster, for example, integrates tasks into email by turning threads into "thrasks" (Bellotti et al., 2003). Thrasks combine an email thread with attachments, files, and bookmarks. In addition, users can add actions and reminders to a thrask, triggering visual cues in the thrask display. This is one of the most elegant interfaces developed so far to support all three of Kirsh's affordances in a single display. Taskmaster was evaluated through a short-term deployment with a small group of technical users. While the scope of the evaluation was limited, the positive results were still encouraging because the system was used to support users' real day-to-day work practice.

Alternative approaches have been proposed in the UMEA (Kaptelinin, 2003), TimeSpace (Krishnan & Jones, 2005) and Univeral Labeler (Jones, Munat et al., 2005) systems. UMEA tracks activity in Microsoft Office applications to provide a project-based interface that combines to-do lists, notes, calendar, and a history of activity (such as file creations and modifications). UMEA's display of action and reminding cues is less efficient and pleasing than Taskmaster's, but UMEA's history feature automatically supports rapid access to recently used files within a particular project. TimeSpace likewise provides chronological, activity-oriented workspaces, but more with complex visual layouts intended to support spatial organization. The Universal Labeler also provides a project-centric view of personal information. It provides a special folder called "My Projects" in which users can create folders and subfolders to represent personal projects. A "Label With…" option in standard file dialogs allows users to associate any type of file one of these projects. In addition, reminders and due dates can be associated with any item in this special folder. The main strength of the Univeral Labeler is the lightweight way in which it integrates into multiple applications. However, it does not provide Taskmaster's visual cues, or a fully integrated project interface like UMEA.

Designers have made significant strides toward developing interfaces that support task management affordances better than current solutions (email clients, task lists, and file folders). Individual systems have focused on addressing particular perceived problems (Taskmaster tackled email overload; UMEA and the Universal Labeler addressed project and information fragmentation). Interfaces that incorporate the best of these alternative approaches have yet to appear, so an open challenge is to explore designs that extend the successful idea of integrated, project-centric task management and reminding.

Since the three systems discussed here all addressed the challenge of "integration" in distinct ways, it appears there are further possibilities for combining disparate information types (such as reminders, task structure, communication, and so forth) into useful interfaces. Since MyLifeBits is not focused on providing reminding and task management support, this research concentrated on understanding students' practices and needs to inform design in this area. In addition, it is not clear that the task management needs of knowledge workers, which underlie most design efforts, are comparable to those of other user groups. Students, for example, may have greater needs for reminding, but less concern with email overload, than a typical knowledge worker. A further area for research, then, is developing task management interfaces better suited to particular user groups and domains. The field research component of this study focused on undergraduate honors students in a general biology class. These students are mostly freshmen and sophomores, highly intelligent (relative to both the undergraduate population and the general population), but generally less experienced with task management than older users. The results from my research therefore complement previous studies by exploring the unique needs and practices of these students.

Sensemaking and making order

Another reason why desktop search is not a sufficient solution for PIM is that users desire personal collections that "make sense." It is reassuring to know that one's digital files are organized in some meaningful way. Furthermore, this organization supports browsing and understanding of the available information, a function that is particularly important when returning to information after some time. Cataloging and metadata creation field studies have characterized these activities as "making order" (Levy, 1995; Marshall, 1998). In the process of developing and assigning metadata, catalogers iteratively understand and structure the collection as a whole. Users in social bookmarking systems take on similar roles (Hammond et al., 2005). This process is mirrored in PIM, as users develop folder structures based on personally meaningful classifications such as task and genre (Henderson, 2005).

PIM systems should support these order-making (and reorganization) activities. However, identifying precise user needs and goals in this area is difficult, both because of highly personal nature of making order, and the limited research focused on this issue. Intuitively, it appears there are a small number of key organization methods that people would typically use in practice. For example, Henderson's study identified genre, task, topic and time as primary facets in participants personal folder structures, with other facets playing a fairly minor role. Research should examine whether this assumption holds for different types of users and work contexts.

User Needs

PIM systems should support users in making meaningful order within their personal collections. However, identifying precise user needs and goals in this area is difficult, both because of the highly personal nature of making order, and the limited empirical research focused on this issue. In general terms, we can say that PIM systems should enable users to create personal collections that can be flexibly organized in meaningful ways and contain meta-information about content and structure. I take the view that classification serves as "cognitive scaffolding" (Jacob, 2001) and that the act of classifying is itself a process of a learning and making sense. By the same token, though, classification is cognitively demanding (Bruce et al., 2004; Jones, 2004; Malone, 1983), so effective interface support for classification and metadata creation is critical.

Approaches

In some ways, MyLifeBits represents the state of the art in support for order making. By allowing users to define collections that can incorporate many types of objects, MyLifeBits enables highly personal classification that is far more flexible than the hierarchical and application-specific structures typical of modern desktop systems. In addition, MyLifeBits allows simple annotation of individual objects within these collections.

Other systems support more extensive and complex metadata for personal information. The Windexer (Hinrichs, Pipek, & Wulf, 2005) enables the definition of custom metadata for documents in a document management system. Administrators can create input forms with appropriate default values; end users then create metadata for their own documents using these forms. Popcorn (Davies et al., 2006) supports the development of a "personal knowledge base" using interconnected concept maps. These maps support visual, associative connections among concepts, as opposed to collections of information objects. However, information objects can easily be added to the Popcorn store (e.g., by dragging-and-dropping from a Web page into a concept map).

Interfaces have also been developed to help users understand (gain an overview, and assess depth, breadth, and methods of organization) a collection as a whole, which could support more effective order making. As Chang et al. (2004) note:

> The goal here is to understand the entire collection by comprehending the "whole as a sum of the (relationships among the) parts." By "parts", we mean a subset of artifacts in the collection. Users should be able to iteratively

specify subsets, visualize the resulting collection artifacts easily and derive their own understanding (p. 334).

Their "collection understanding" interface for a fine arts digital library presents collages or grids of images which can be dynamically filtered using metadata fields. However, comprehensive evaluation of this interface was not reported, leaving open the question of whether this approach effectively supports collection understanding. Analogous interfaces for personal collections can be envisioned, but it in some cases in can be more difficult to support rapid consideration of different views with largely textual information. A challenge for system designers is to incorporate methods for examining different subsets of textual collections. These subsets might include aspects of documents such as date and length as well as aspects of use, such as popularity.

Effective support for collection understanding does not necessarily require complex visualizations. mSpace (schraefel et al., 2005) provides an interaction model, inspired by the original Memex vision, to enable exploration of a collection using annotations, paths, and preview cues. This model is analogous to AgileViews (Marchionini, Geisler, & Brunk, 2000), and the current mSpace UI is comparable to RB++ (Zhang & Marchionini, 2005), albeit based on a Semantic Web framework. Both mSpace and RB++ allow users to gain a sense of a collection by browsing overviews, using previews to provide a quick look at item content, and enabling rapid "slicing and dicing" of collections using facets and attributes. Neither of these approaches has been evaluated in the context of a personal information collection.

Overall, interface support for "making order" within the PIM context appears to still be nascent. Open challenges include making the cognitively difficult, but worthwhile, tasks of classifying and annotating easier, more visible and more appealing. At the same time, designers should consider that not all manual classification and annotation is necessarily valuable (Bulterman, 2004; Liddy, 2002). More powerful interfaces for exploring and understanding personal collections are also clearly needed.

Reflection and metacognition

Metacognition is essential to learning and being able to apply what one has learned. Metacognition is broader than the literal sense of "thinking about thinking"—it is a component of the general psychological ability of "self-regulation" (Hacker, 1998).

Metacognition comprises two broad areas: "knowledge of cognition" and "regulation of cognition" (Schraw et al., 2006). Knowledge of cognition includes *declarative* knowledge (i.e., knowledge "about ourselves as learners"), *procedural* knowledge (i.e., knowledge "about strategies"), and *conditional* knowledge (i.e., knowledge about "why and when to use a particular strategy").

In contrast, "regulation of cognition" encompasses *planning* ("selection of appropriate strategies and allocation of resources"), *monitoring* ("self-testing skills necessary to control learning"), and *evaluation* ("appraising the products and regulatory processes of one's own learning").

Metacognitive processes in general tend to be highly automatized and are often developed without conscious reflection and processing. Reflecting on one's activities (and particularly for students, one's learning processes) can help develop further develop metacognitive abilities. Ishii & Miwa (2005) argue that engaging students in reflection can help them realize the characteristics of creative processes and learn the importance of metacognitive activities. More broadly, reflection can help support personal growth and building a "life story" (McAdams, 2001). Levy (2005) argues for the importance of enabling reflection and contemplation in an accelerated environment of pervasive information overload. Papert (1980) describes how playing with gears, and learning how cars work, as a child sparked a lifelong love of mathematics. He emphasizes how he was able to relate abstract mathematical concepts, such as systems of equations, into his familiar gears—a very playful form of metacognition.

User Needs

Kirsh (2005) argues for the importance of "affordance landscapes." These landscapes "display cues and constraints to bias what users see as their possibilities for action" (p. 150). Users need "well-designed affordance landscapes [that] make metacognition easier" because they "serve as indicators, letting students or users know when they are getting closer to one of their goals" (p. 150). The design challenge is to create tools (e.g. a homework tracker) that cue and prompt users effectively, and encourage them to reflect upon activities after the fact and note new cues (which can then be entered into the affordance landscape). The tools should specifically enable users to track where they are (in a task or activity), understand what remains to be done, and indicate that they don't understand something.

Luchini, Quintana, & Soloway (2004) further argue that learner-centered software "incorporates scaffolds to assist learners in working mindfully within an unfamiliar domain" (p. 136). Since, as noted above, metacognition is highly automatized, students often need scaffolds to understand and engage in metacognition. Luchini, Quintana, & Soloway identify five guidelines for developing effective scaffolds:

- visibility (scaffolds should be obvious, almost intrusive)
- essentialness (scaffolds should be central to completing the task at hand)
- coupling (scaffolds should be tightly integrated with the task)

- usability (scaffolds should be fluid to use, and create engagement with the task)
- representation (scaffolds should use combinations graphics and text as appropriate)

To support reflection, users need raw material—something to reflect *on*. In a study of reflection among engineering students, it was found that "if participants had been given no information on their processes, they would have forgotten their own detailed processes" and so been unable to reflect deeply on their work (Ishii & Miwa, 2005). The need to capture the raw material of experience supports PIM systems broadly, as well as sensor-based capture, such as the SenseCam (Gemmell et al., 2004) and related technologies. The question is whether these systems effectively capture and present data that cues memory and supports meaningful reflection. In particular, an important issue for research is to what extent selective recording devices (such as the SenseCam) can support specific learning and PIM tasks.

Approaches

Schraw et al. (2006) identify six major types of systems that support metacognition:

- concept mapping
- cognitive scaffolding

- electronic assessment systems
- data analysis/visualization
- modeling
- electronic communication and collaboration

Azevedo (2005) also identifies four areas in which computers can serve as "metacognitive tools:"

- supporting cognitive processes
- sharing the cognitive load
- scaffolding (allowing learners to take on complex cognitive activities)
- supporting problem-solving via generating and testing hypotheses

Of these, it is cognitive scaffolding and electronic communication and collaboration that are most closely related to typical PIM systems. For example, Schraw et al. advocate systems in which students can be "prompted to post notes that use language to support knowledge building" (p. 128). This activity could be supported by an annotation function.

Systems can support reflection based on analysis of life experiences. These systems provide the "raw material" of reflection. RAW (Jo et al., 2004) takes this approach quite literally, providing "minimally mediated" audiophotographs which are intended to spur reflective analysis of everyday life activities.

Similarly, mobile UI researchers have proposed smart phones that capture, log, and present media and communication from daily phone use (Rhee, Kim, & Chung, 2006).

While these systems provide fairly simple ways of structuring captured information, other approaches focus on rich interfaces for browsing the raw material and incorporating it into life stories. The Affective Diary (Madelene et al., 2006) uses color and animation to visually represent captured sensor data, encouraging interpretation of and reflection upon these data. iTell (Landry & Guzdial, 2006) supports the creation of digital narratives, combining pictures, sound, and text, that can relate personal stories for oneself and others. Quill (Daniel & Jorge, 2006) encourages users to describe documents using stories, which both elicits reflection and provides a narrative basis for later retrieval.

Overall, designers are only beginning to explore the link between PIM (particularly task management), automatic capture, and metacognition and reflection. Kirsh notes that "our goal is to understand the principles that affect cognitive effort and metacognitive decision making and incorporate these into our environments" (p. 178). Future research should seek to better understand metacognitive practices (Pressley, Van Etten, Yokoi, Freebern, & Van Meter, 1998) and explore further possibilities for using PIM capabilities to provide scaffolds for metacognition and reflection (Fleck, 2006). Finally, the sociocultural influences on reflection, metacognition, and related concepts such as *forgetting* (Nack, 2005) should also be examined.

2.4.2 Conclusion

I have identified four major types of tasks—*refinding, reminding and task management, order-making, and reflection and metacognition*—which could be supported by PIM systems. Analysis of the HCI and PIM research literature shows that there has been extensive work on the first two types of tasks—refinding and reminding—but much less consideration given to making order and supporting reflection and metacognition. Innovative designs have been proposed in each area, but only rarely are these designs carefully evaluated in a realistic use context. As Boardman (2004) notes, there is "a break in the task/artefact cycle... Studies of user practices are not providing firm grounding for design, which is in turn not being systematically evaluated" (p. 57). Future research should address this break by evaluating the use of the PIM systems in context, and by exploring new possibilities for supporting PIM needs for different user groups and domains.

2.5 Qualitative field methods

2.5.1 Introduction

A number of methodological issues arise when conducting qualitative research in field settings. The fieldwork conducted for this dissertation considers technically realistic design solutions for student-centered PIM systems. One goal of this research was to avoid being overly constrained by current system design, so as to be able to develop a fundamental understanding of students' PIM needs that transcends current technological solutions. The qualitative research design allowed a more holistic view of students' PIM behaviors and practices, complemented with simple quantitative measures, such as frequency counts and descriptive statistics, where appropriate.

Overall, the process of designing an effective qualitative field study involves three key components:

- understanding and *applying an appropriate research perspective*
- *choosing methods* to gather data
- *ensuring the credibility* of these methods through appropriate sampling, research techniques, and verification

In addition, I specifically address three research perspectives—design research, humanistic research, and institutional and infrastructural research—that informed my work.

Design research

The principal research perspective for my work is *design research* (Boardman, 2004; Carroll, 2000; Rosson & Carroll, 2003). Design research typically focuses on system design, but could also apply to services, information, or other areas of inquiry. In this type of research, the researcher first seeks to understand user needs through user research. User research entails developing a deep understanding of people in a particular domain—their practices, culture, and so forth. In contrast to general social scientific research, which seeks to build theories and models of individual and group behavior, user research seeks to understand behavior in order to support design. This distinct point of view influences both the techniques and interpretations of research. The findings from user research can often be presented as set of user *personas* (brief profiles of composite, archetypal users) and *scenarios* (high-level narrative descriptions of user activities and tasks) (Courage & Baxter, 2005; Pruitt & Adlin, 2006; Rosson & Carroll, 2003).

User research can support an iterative design process, in which design concepts and prototypes are created, and then evaluated by both designers and representative users (McClelland & Suri, 2005). The evaluation identifies problems with and opportunities for improving the design. An example of this approach in a research context is the Open Video Project. To create this system, researchers designed and tested interfaces for accessing video using an iterative feedback process. This feedback loop created a "Mobius strip" of design and evaluation, and research and practice (Marchionini, Wildemuth, & Geisler, 2006).

Ultimately, designs are refined into forms (*artifacts*) ready to be regularly used, such as a deployed research prototype, or a commercial or open-source product. As people use the artifacts, further opportunities for design and research become apparent (the "task-artifact" cycle, (Rosson & Carroll, 2003). Moreover, a broader assessment of the strengths and weaknesses of the design can be created. This set of claims about a design can then be generalized to a "design genre" of similar artifacts (Rosson & Carroll, 2003). The claims abstract from the myriad details of particular artifacts, identifying principles on which future design work can build.

In current PIM research, there is "a break in the task/artefact cycle… Studies of user practices are not providing firm grounding for design, which is in turn not being systematically evaluated" (Boardman, 2004), p. 57. The goal of this dissertation was to help address this break by exploring the use of a PIM system in context. This exploration helped to develop an understanding of students' PIM behaviors and practices, and then to find new possibilities for supporting students' PIM needs through design. This research concentrated on the initial stage of design (often referred to as "conceptual design" (Norman, 2006)). *Evaluation* of a system plays a less central role in the research reported on here, as the primary purpose of deploying the MyLifeBits system in the field was to deepen the user research and suggest new directions for design rather than to evaluate the current implementation of the system.

The following subsections discuss how the design research perspective can be qualified by considerations of humanistic research, and the role of institutions and infrastructure.

Humanistic research

One criticism of design research is that it has focused too narrowly on designing technological "solutions" to users' "problems" while neglecting a broader understanding of people's needs, capabilities and interests (Norman, 2005). *Humanistic* research has been proposed as an alternative perspective to address this concern (Oulasvirta, 2004). According to this perspective, humanistic research has three main characteristics: *relevance*, *understanding*, and *empowerment*. Humanistic researchers "aim to address problems or needs that are relevant to people" (p. 247). It is not sufficient to solve problems, even if the problems are derived from users. For example, in the context of PIM research, desktop search has "solved" the problem of quickly retrieving local files based on particular keywords. However, it is not clear how relevant this problem is, as many people prefer to browse local files (Ravasio et al., 2004). In general, humanistic research emphasizes that the problems or needs to be addressed must be relevant and meaningful to people in the context of their lives and work.

To deal with relevance, humanistic researchers acknowledge that "all design must be based on a holistic understanding of people and their activities" (p. 248). This holistic understanding specifically includes *psychological*, *social*, and *ethical* issues. Design should seek to empower people, not merely to automate functions (Mainwaring et al., 2004). Researchers should "provide tools and services that empower and enable people themselves to address their social, rational, and emotional needs" (p. 248). These needs may include *equality*, *autonomy*, and *control* (Oulasvirta, 2004). This view is quite distinct from an engineering perspective, in which solving the identified problem efficiently is the primary concern. From the humanistic research perspective, a system that addressed a user need in a moderately inefficient but elegant and usable way would be preferred to one that addressed a user need in an efficient but opaque and uncontrollable way (Hallnäs & Redström, 2002). Similarly, McClelland & Suri (2005) argue for "human-centered design," encompassing "life-styles, aesthetic considerations, and emotional value" (p. 286).

Like design research, the humanistic perspective influences both the techniques and interpretations of research. Humanistic researchers tend to employ a broader range of exploratory methods, such as cultural probes (Gaver, Dunne, & Pacenti, 1999), while placing less value on strictly evaluative techniques, such as usability testing (Nørgaard & Hornbæk, 2006). Humanistic research is also broadly analogous to *action research* (Hignett, 2005), particularly *critical design ethnography*, which aims to facilitate social change through designs that empower groups and individuals (Barab, Thomas, Dodge, Squire, & Newell, 2004). While fieldwork is well-accepted in design research, humanistic researchers and critical designers seek a broader range of understandings in fieldwork. They investigate what people feel, as well as what they say and do. They consider that "the drivers for action are often complex, subtle, and closely tied to culture, meaning, and context" (Wilkens-Adessa, 2006). This focus on culture, meaning, and context links humanistic research to perspectives that focus on institutions and infrastructures, discussed in the next subsection.

Institutions and infrastructure

The institutional perspective looks for "recurrent social patterns that structure and provide settings for action" (Barkhuus & Dourish, 2004, p. 234) (p. 234). The idea is to find these patterns amid people's typical, mundane activities. Based on a close examination of these activities, one can ask how institutional arrangements affect peoples' daily activities and practices, and therefore their needs and uses of technology. For example, college students have very nomadic, but highly scheduled lives, driven by the institutional structures of colleges and undergraduate curricula (Barkhuus & Dourish, 2004).

This focus on institutions in the context of mundane, everyday experience is closely associated with ethnomethodology. Ethnomethodology examines how people communicate and generate social structures, with particular emphasis on "ordinariness" (Crabtree et al., 2006; Crabtree, Nichols, O'Brien, Rouncefield, & Twidale, 2000; Dourish, 2004). Chalmers (2004) further identifies five themes that characterize ethnomethodology: human agency, self-reflection, language as a "medium of practical activity," the temporal and contextual nature of action, and the importance of "taken for granted" understandings in social interaction and understanding.

So by taking an ethnomethodological point of view, researchers can gain a better understanding of people's "ordinary" activities and needs, which can inform design. As Button (2000) notes, "it is the explication of members' knowledge—what people have to know to do work, and how that knowledge is deployed in the ordering and organisation of work" (p. 319) that is of greatest value to design. For example, an ethnomethodological inquiry into how students' form study groups might reveal various processes of negotiation to create the social structures that support studying. Understanding these processes and structures would help designers develop communication tools for students.

A major challenge for designers is to move from an ethnomethodological understanding of people's activities and interactions with institutions to design tools that "fit" in a broad sense. Specifically, designers should understand that "the designed intervention or artifact positively depends on users transacting with the work, each other, and their multiple social systems in order for the design to serve *as a tool that is part of the system*" (Barab et al., 2004), p. 257. In other words, tools and systems are adopted and used as part of a larger sociocultural system, such as a classroom and educational institution (Sutherland et al., 2004). For example, as PowerPoint has been adopted in organizations, it has been both appropriated for unexpected purposes, and moved discursive practices in new directions (Yates & Orlikowski, in press). The use of PowerPoint has changed how people prepare for and give presentations. In addition, PowerPoint decks are often widely shared, unlike earlier tools such as physical transparencies and slides.

This view is consistent with the humanistic research position of seeking relevance, understanding, and empowerment. To create such a fit between activities and tools, it is helpful to examine *infrastructures* as well as institutions. Infrastructures are underlying frameworks or foundations of a system that people continually rely on as "invisible." Three general classes of infrastructure have been identified (Barkhuus & Dourish, 2004): *technical* (such as systems and networks), *procedural* (such as administrative mechanisms, forms, and rules), and *conceptual* (such category systems and schematic models). It is when difficulties and breakpoints are encountered that infrastructures become apparent and problematic (Barkhuus & Dourish, 2004; Mainwaring et al., 2004). When difficulties occur, people refocus on infrastructures, considering how they work and why they are not working. Chalmers (2004) distinguishes between *breakdowns* (e.g., the confusion experienced when a cell phone loses its signal), *analysis* (e.g., actively moving a cell phone around to try to acquire a better signal), and *contemplation* (e.g., amazement or curiosity upon seeing a new capability).

Researchers explicitly examine infrastructures and how people come to experience them in order to identify otherwise latent needs and problems with systems. One analysis of infrastructures led to the conclusion that "systems need to be designed that not only provide tangible benefits to 'users,' but which provide multiple symbolic and social values to people who will adopt many different roles and stances towards them." (Mainwaring et al., 2004), p. 426. For example, people may need "quiet sanctuary," to support contemplation, as much as they need tools to manage information (Levy, 2005; Mainwaring et al., 2004).

Summary

An objective of the research reported on here is to understand how students manage their personal educational information, and identify opportunities for technically-realistic design solutions for student-centered PIM systems. Because it can be limiting to focus too closely on existing technology and system design (Dourish, 2006), this research emphasizes a holistic understanding of people's activities, practices, and needs. This perspective is balanced with the need to identify useful insights that can contribute directly to designs that can support students' needs.

2.5.2 Approaches and Methods

Methods are "a technique for gathering evidence" (Bisantz & Drury, 2005), p. 63. The thrust of qualitative field research methods is to explore a particular setting in depth and gather a range of data. These data may include the cognitive and social aspects of work; the timing, sequence and structure of activities; conversations; artifacts used; locations; and information sources (Bisantz & Drury, 2005). It is important to emphasize that these data are collected in a "context of discovery" rather than a "context of justification" (Potts & Newstetter, 1997). That is, researchers use these methods to deepen their understanding of an issue, not to test particular hypotheses.

The researcher—particularly in a design research perspective—may act as an *explorer*, an *optimizer*, or an *innovator* (Sinclair, 2005). In these guises, the researcher tries to "tap into the explicit and tacit knowledge and feelings" of participants" (McClelland & Suri, 2005), p. 283. The researcher then goes on to discover or invent ideas beyond participants' own understandings: "Had you asked someone back in the 1970s to tell you what functionality he/she would like in a mobile communication device, it is highly unlikely that person would describe the modern mobile phone" (Sinclair, 2005), p. 90. In other words, the design researcher uses insights from fieldwork to generate new directions for design.

To support these insights, qualitative field researchers typically rely on three basic sources of data: *interviews*, *observations*, and *documents* or *artifacts* (Hignett, 2005; Merriam, 1998b). The sources are rarely examined in isolation—most contemporary studies combine forms of data, a technique often called *triangulation*. Triangulation is more broadly defined as "the use of more than one data source, method, or investigator and the convergence of these to add credibility to a study" (Hignett, 2005), p. 123. By combining methods, researchers hope to minimize the weaknesses of each.

Interviews

Interviews are guided conversations. The amount of guidance can range from highly structured (i.e., the researcher has a set list of questions, and simply records the answers), to semi-structured, to unstructured (i.e., the researcher lets the conversation evolve and meander as needed). The interview can focus on a set of issues that interest the researcher (and respondents), although an interview specifically focused on life experiences might be referred to as a "life history" interview, while an interview focused on an issue or process might be called a "topical interview" (Glesne, 2005).

Interviews are widely used in user research generally (Courage & Baxter, 2005), and in studies of PIM practices in particular. Bondarenko & Janssen (2005) used semistructured interviews to explore how researchers managed paper and digital documents. Barkhuus & Dourish (2004) took a similar approach in examining how students adopted context-aware technologies on campus. Ravasio, Schär, & Krueger (2004) also relied on semistructured interviews when examining problems with everyday computer use. These studies are representative of numerous HCI studies which used interviews to uncover user needs and practices, and thereby inform design.

These studies illustrate both the strengths and weaknesses of interviews as a research method. On the one hand, they revealed a number of interesting insights and patterns in people's use of systems, and their strategies for managing information. On the other hand, many of the reported findings were not particularly deep or novel. For example, both Bondarenko & Janssen (2005) and Ravasio et al. (2004) reported that participants relied heavily on browsing and spatial organization of documents—findings that mirror much earlier studies (Barreau, 1995; Malone, 1983). So while interviews are an efficient and often effective method of gathering data, they may lead to only a surface understanding. It is not surprising, then, that so many contemporary PIM field studies complement interviews with other sources of data, such as observations and documents.

Observations

Research observation entails systematically examining a particular situation with a research question or goal in mind:

> In everyday life you observe people, interactions, and events. Participant observation in a research setting, however, differs in that the researcher carefully observes, systematically experiences, and consciously records in detail the many aspects of a situation. Moreover, a participant observer must constantly analyze his or her observations for meaning (What is going on here?) and for evidence of personal bias (Am I seeing what I hoped to see and nothing else? Am I being judgmental and evaluative?) Finally, a participant observer does all this because it is instrumental to the research goals… (Glesne, 2005), p. 46.

This focus shapes the practice of observation and leads the researcher to explore area and develop ideas that go beyond "everyday" observation.

As with interviewing, observation can be structured in a range of ways. Social scientists working from a positivist perspective often are interested in unobtrusively observing people's behavior. For example, psychologists will often introduce a manipulation in an experimental setting, then observe the effects on people when they are unaware they are being watched. Alternatively, researchers sometimes ask participants to write diaries focused on specific aspects of their behavior. These diary studies allow researchers to "observe" aspects of behavior that the researchers couldn't directly access otherwise. Examples of diary studies include research on how people they use the Web during their work (Sellen, Murphy, & Shaw, 2002) and how people deal with interruptions at work (Czerwinski, Horvitz, & Wilhite, 2004). Written diaries can be enriched using media (photographs, audio, video), an approach that has become feasible with low-cost, portable cameras and phones (Carter & Mankoff, 2005).

In contrast to unobtrusive observation, *participant observation* entails becoming part of a social setting and culture. The researcher develops rapport and trust with the participants that allow access to the complex details of their activities. At the extreme of "participant observation," the researcher and participant merge into one agent, who writes "autoethnography" (Cunningham & Jones, 2005). Within the scope of participant observation, one can further distinguish between research- and theory-oriented approaches, such as *ethnography*, and change-oriented approaches, such as *action research* (Glesne, 2005). That is, the researcher can seek to explain and document a culture (ethnography, literally, means "writing culture"), or to understand, empower, and change a culture.

"Ethnographic" observation is widely referenced in HCI and PIM research (see Dourish, 2006 for a review). However, this research is rarely ethnographic in the anthropological sense. HCI researchers generally do not apply a distinct analytic framework to their field observations, instead focusing on developing practical implications for design (Anderson, 1994; Dourish, 2006). In addition, HCI field studies typically involve only a fraction of the field time typical of a full ethnographic study in anthropology or sociology (Millen, 2000). As a result, HCI researchers have turned to more structured forms of observation, such as *contextual inquiry* (Beyer & Holtzblatt, 1999). In contextual inquiry, the researcher acts as an "apprentice" to the participant, the better to learn about the participant's work practices. This mode of openness to learning is combined with observation of the participant's daily work routine. It is argued that the contextual inquiry approach allows designers to build a solid understanding of work practice with perhaps twenty contextual inquiry sessions (as opposed to weeks or months of ethnographic observation) (Beyer & Holtzblatt, 1999).

Another approach is to conduct *field trials* of a new system, observing users as they interact with it. This approach was used with early prototype versions of

Microsoft's Tablet PC system, and led to useful insights into the use of the system in practice (Dray, Siegel, Feldman, & Potenza, 2002). When exploring new technologies that have not yet been prototyped, researchers have developed *technology probes* that instantiate specific aspects of the new technologies (Hutchinson et al., 2003). Observing people's use of these probes can shed light on their perceptions of the proposed technologies (Rogers et al., 2002).

Overall, observations seem to be much less efficient than interviews, and it can be difficult to focus observations on the research issues of interest. The payoff is that they provide a different class of data and insight. Arguably, one of the weaknesses of PIM research is that it has neglected observation as a research method. Numerous studies have conducted "ethnographic interviews" (Ravasio et al., 2004) and contextual inquiry (Bondarenko & Janssen, 2005; Teevan et al., 2004), but it appears few have engaged in true participant observation and studied a setting over an extended period of time. It seems likely that more extended observation would have provided a different outlook on PIM practices, as it has in other domains. For example, Crabtree et al's (2000) ethnographic study of interactions at a reference desk led to a better understanding of how signs, social conventions, and the physical environment structured people's understanding of the library and how to find information within it.

Documents and artifacts

A fundamental limitation of both interviews and observation is the interaction between the observer and the participants—an interaction motivated and guided by a specific research goal. While this interaction may be desirable (as in action research), in some cases researchers prefer to examine a form of data that derives naturally from people's own behavior (Merriam, 1998a). *Documents* are the main form of this type of data. "Documents" is often used in a broad sense to include a range of written, visual, and physical materials that researchers can examine (Merriam, 1998a). Many researchers also use the term *artifacts* to refer to this broad class of materials, which include documents, pictures, tools, and so forth. In a typical work setting, these might include manuals, forms, handwritten notes, emails, letters, memos, travel receipts, and so on (Courage & Baxter, 2005). In a personal setting, artifacts might include "behavioral traces" of people's behavior, such as what objects they choose to display in their bedroom and how they arrange these items (Gosling, Ko, Mannarelli, & Morris, 2002).

Personal documents are particularly interesting in PIM research because they are the raw material which people presumably try to "manage." Numerous studies have examined participants' physical and virtual documents (and the structure of those documents) to assess people's PIM strategies (Barreau, 1995; Henderson, 2005; Malone, 1983). When the research involves discussing documents and artifacts with participants, researchers often refer to an "artifact walkthrough" (Bondarenko & Janssen, 2005). The purpose of the walkthrough is to "understand what triggers the use of each artifact: when is it used, and for what" (Courage & Baxter, 2005).

Document and artifact analysis is a core method of PIM research. Many key findings of the PIM field result from analyses of participants' files, folders, and documents. The great danger of analyzing documents is they may lead to erroneous assumptions about people's behavior. For example, observation of seemingly haphazard folder structures might lead a researcher to conclude that people do not value organizing their personal information, and would prefer automated indexing and retrieval. But interviews and observations would suggest otherwise—people greatly value being able to browse through meaningful folder structures (Teevan et al., 2004).

2.5.3 Validity and Credibility

The previous two sections discussed adopting a research perspective to frame the research strategy and goals, and choosing specific research methods to meet the research goals. A third and critical component of a research plan is to produce valid and credible results—conducting research using an appropriate perspective and methods will be of little value if the results from the study are not convincing. As Hignett (2005) notes, "At a fundamental level one aim of all research should be to convince the reader" (p. 123).

What is required to "convince the reader"—to provide credible research results from qualitative field research? In design research, the ultimate measure of success is the quality of designs produced—even though this outcome cannot be fully attributed to the quality of the user research. Moreover, the critical design ethnography and action research perspectives both caution against measuring success in terms of "solutions"—one must remain concerned with how people themselves are empowered. Techniques for developing valid and credible qualitative results, developed in the social sciences, can inform both of these perspectives. Researchers generally agree on three primary approaches for ensuring credible results: *sampling*, *research technique*, and *verification* (Glesne, 2005; Hignett, 2005; Maxwell, 2005).

Sampling involves the selection of situations, times, people, and artifacts to observe, interview and analyze (Hignett, 2005; Maxwell, 2005). Positivist, quantitative research typically relies on equal-probability (also known as "random") sampling. By contrast, interpretive and qualitative research typically employs *purposeful* sampling, "in which particular settings, persons, or activities are selected deliberately in order to provide information that can't be gotten as well from other choices" (Maxwell, 2005) (p. 88). Non-random sampling is often characterized as "convenience" sampling, but truly purposeful sampling is intended to sample in a way that leads to credible, useful results. With this goal in mind, Maxwell (Maxwell, 2005) identifies four factors that should be considered:

1) the representativeness or typicality of the sample
2) the extent to which the sample captures the diversity or heterogeneity of the population
3) the extent to which the sample contains cases (individuals, artifacts) critical to the research questions, issues or theories
4) the extent to which the sample allows comparisons between specific differences of interest

The researcher must weigh these different factors when seeking the overall objective of an effective sampling plan. In addition, these factors cannot be considered in isolation—the feasibility of the sampling plan and the researcher's relationships with participants will influence many studies (Maxwell, 2005).

Another important step in ensuring credibility is choosing appropriate research techniques. In field work, it can be difficult to see people's natural behavior—they may be nervous in the presence of a researcher, or seek to please the researcher by providing "desired" information. Researchers have suggested a combination of three techniques to combat this tendency (Bisantz & Drury, 2005):

1) explain the observer's role, so participants become understand why the researcher is conducting the study, and that they are not being evaluated or judged

2) remain in the setting for an extended period of time, so participants can be become comfortable

3) focus on situations where participants are directly engaged in tasks, which is when people lose self-consciousness and anxiety

Finally, researchers can seek to verify their research results. Three primary methods for verification have been proposed (Bisantz & Drury, 2005; Maxwell, 2005):

1) conduct "member checks"—that is, test ideas developed during the research by speaking directly with participants

2) triangulate results with "parallel measures," such as log or archival data, questionnaires, and focus groups

3) compare results with previous research in the field, or analogous studies in other fields

Each of these approaches can support research that "convinces the reader." For example Bellotti et al. (2004) used a diverse sample of participants, met with participants multiple times over an extended period, combined interviews with document analysis, and conducted member checks of their findings. These efforts led to credible conclusions about task management practices in a research organization. These approaches can also be used to identify discrepancies in the research results. For example, participants might challenge the plausibility of ideas proposed by the researcher, which could then be refined into stronger propositions. Once verification no longer yields significant discrepancies, the research results will have gained coherence and credibility.

2.5.4 Conclusion

The process of designing an effective qualitative field study involves understanding and *applying an appropriate research perspective*, *choosing methods* to gather data, and *ensuring the credibility* of these methods through appropriate sampling, research techniques, and verification.

These issues are framed by research perspectives, including design research, humanistic research, and institutional/infrastructural research. The design research perspective, which is central to this dissertation research, emphasizes the importance of understanding user needs through user research. User research seeks to understand behavior, particularly through field research, in order to support design. The findings from user research can then support an iterative design process, in which design concepts and prototypes are created, and then evaluated by both designers and representative users. The evaluation identifies problems with and opportunities for improving the design. Ultimately, designs are refined into forms (artifacts) ready to be regularly used, such as a deployed research prototype, or a commercial or open-source product. As people use the artifacts, further opportunities for design and research become apparent.

Within the design research perspective, a range of methods and techniques can be used to gather data. Since every method has limitations, most studies combine (or "triangulate") different forms of data collection. A key challenge is ensuring that the data (and subsequent) analysis are credible and trustworthy. Qualitative data are sometimes naively equated with anecdotes. But when qualitative researchers incorporate extended observation, rich description, and verification of findings and themes with participants and other sources of evidence, the results can be highly credible. Therefore, qualitative field research, conducted from a design research perspective, can fruitfully inform the design of student-centered PIM systems.

Chapter 3: Research methods

3.1 Research context

The principal research perspective for this work is *design research* (Mangiafico, 2007). In this type of research, the researcher first seeks to understand user needs through user research. User research entails developing an in-depth understanding of people in a particular domain—their practices, culture, and behaviors. In contrast to general social scientific research, which seeks to build theories and models of individual and group behavior, user research seeks to understand behavior in order to support design. This distinct point of view influences both the techniques and interpretations of research.

The findings from user research can inform an iterative design process, in which design concepts and prototypes are created, and then evaluated by both designers and representative users. The evaluation identifies problems with and opportunities for improving the design. Ultimately, designs are refined into forms (artifacts) ready to be regularly used, such as a deployed research prototype, or a commercial or open-source product. As people use the artifacts, further opportunities for design and research become apparent.

The design research perspective motivated two components of this research. The first component is *ethnographic fieldwork*, in which I examined students' PIM *practices and behaviors* through intensive participant observation and interviewing. The second component is a *technology probe*, in which I examined how students used MyLifeBits, an advanced PIM system developed by Microsoft Research. Both components of the research were intended to identify particular PIM practices that can be better supported by PIM systems, so as to inform the design of next-generation PIM systems.

3.1.1 PIM behaviors and practices

This approach is consistent with current needs for research on PIM behaviors and practices. As Boardman (Mick & Fournier, 1998) has noted, the PIM field has seen extensive design and prototyping work, but little user research and evaluation. Thus, "many of the PIM prototypes... are not grounded in a firm understanding of user problems" (p.49). There is a fundamental "break in the task/artefact cycle. Studies of user practices are not providing firm grounding for design, which is in turn not being systematically evaluated" (p. 57). In particular, most fieldwork has concentrated on narrow slices of the overall PIM problem (e.g., the numerous studies on email filing and management practices).

The purpose of this study was to take a more holistic approach to support next-generation PIM system design and research. The overriding goal was to identify opportunities for PIM system design in education that go beyond existing approaches (such as typical digital desktop file systems, or MyLifeBits' collections and annotations).

3.1.2 Information architecture and user interface design

The design component of this research is based on an *information architecture* (IA) perspective (2006). The IA encompasses how information is organized, structured, and represented within an information system. Rosenfeld and Morville (2006) identify four key components of IA: organizing, labeling, navigating, and searching. Closely linked to the IA is the *user interface* (UI), which includes the overall layout and screen design, specific interaction styles, modes, and widgets (e.g., tabs, dialog boxes, panes, forms, etc.) and task flows. The UI enables users to access information and complete tasks within the context of the IA. Finally, metadata is used in IA to connect information objects (resources) to the organization, labeling, navigation, and search systems, and the UI mechanisms that provide access to the systems. In other words, metadata provides the "glue" between the IA and the UI.

3.2 Research procedures

The following sections summarize the development and structure of the specific procedures developed to address the following research questions:

Research Question 1. What strategies and practices do undergraduate students use when they manage and retrieve their personal educational information?

- What types of information do students seek, retrieve, and manage?

- How do students use technology when engaging in the four primary PIM tasks (refinding; reminding and task management; making order; reflection and metacognition)?
- What elements of context (including task, social, physical, and temporal context) influence students' PIM practices?

Research Question 2. How do students use the MyLifeBits[2] system?

- Is it effective and efficient in practice?
- How do students structure their MyLifeBits store, and how does this structure evolve with use?
- What are the interaction design issues need to be addressed in future designs?

Research Question 3. What design requirements and directions could improve a student-focused PIM system to facilitate learning, reflection, and metacognition?

3.2.1 Pilot studies

To prepare for the ethnographic research (described in more detail below), three pilot studies were conducted:

[2] MyLifeBits is part of Microsoft Research's Digital Memories project (see http://research.microsoft.com/ur/us/fundingopps/RFPs/DigitalMemories_Memex_RFP.aspx).

1. A baseline study, consisting of observations of biology classes and semi-structured interviews with biology faculty and students.
2. A usability study of MyLifeBits.
3. A pilot deployment of MyLifeBits, involving day-to-day use of the MyLifeBits system by students and professionals.

I describe these studies in more detail below; see also Crystal (Kerne, Smith, Choi, Graeber, & Caruso, 2005) and Barreau et al. (Fleck, 2003; Moon, 1999).

Baseline study: Interviews and observations with students and faculty

In the pilot studies, I conducted interviews, shadowing, and immersion with students and instructors in three undergraduate biology classes: BIO 184 (Conservation Biology), BIO 54 (Population Biology), and BIO 11 (Principles of Biology).

I conducted semi-structured interviews with four biology faculty members. These interviews focused on instructors' goals and approaches to the course they taught, including course content and learning objectives, teaching strategies, expectations of students, and grading. The purpose of the instructor interviews was to gain an overview of how these instructors approach their teaching, and what demands they make of their students. Sample questions included:

- What are your goals for this course?

- Can you walk me through how this activity (e.g., lab session) would be conducted?

I also conducted semi-structured interviews with students recruited from the three classes. These interviews focused on students' note-taking practices, organization practices (use of notebooks, computer files, etc.), collaboration practices, and perceptions of the difficulty of gathering and organizing information for course. Figure 9 presents an example of a student's Windows file system from her personal laptop, collected during this study. Sample questions included:

- Do you take notes during your labs? Can you show me an example?

- How was the quiz last week? What did you use to help you study for it?

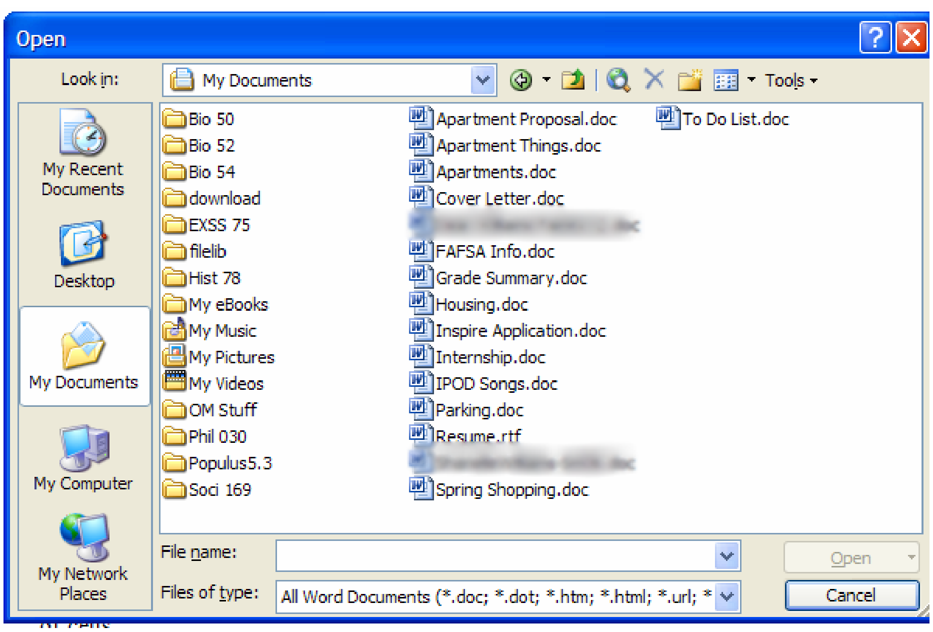


Figure 9. Screenshot of a student's file system.

As part of this study, I also observed selected sessions of each class. My observational analysis involved looking for patterns of information capture and use in students' activities, such as taking notes and collaborating. This research demonstrated that students face some of the same PIM challenges identified in previous field studies, including difficulties integrating different sources of information (such as email, Blackboard e-learning materials, and paper notes). In addition, students reported fairly minimal engagement in reflective learning activities. Observation of classes revealed that a large amount of intangible information, such as the subtleties of student-instructor discussions, is not being fully captured. For example, students rarely took notes on the key points identified in an exchange with an instructor after a student raised a question in class. These results helped to shape this dissertation research by emphasizing the many nuances of students' information use that require extended fieldwork to better understand.

Usability study of MyLifeBits

The usability study was designed to assess how effectively students could use the MyLifeBits system to conduct realistic tasks, based on actual class activities from a local flora class (developed with biology instructors at UNC). In this study, participants (both undergraduate and graduate students) completed a field identification task using the SenseCam and a tablet PC running MyLifeBits. The SenseCam is a wearable digital camera with onboard sensors; MyLifeBits is a PIM system that provides a single interface to many types of information on a PC. (See "technology probe," below for further information). Participants then returned the following day to complete an identification and organization task using the software.

This study was intended to provide a sense of how easily students can master the system and how effectively it works to support a realistic educational task. In this study, students were generally able to learn how to use the system with some training. Students were able to use the system to complete the identification and organization tasks, even though it was their first time using the software. These results informed this research by showing that MyLifeBits can be learned and used by undergraduate students. In addition, this study reinforced my belief that the interface design of PIM systems such as MyLifeBits is an important area for consideration.

Pilot deployments of MyLifeBits

In order to assess the reliability of MyLifeBits in day-to-day use, two staff members in ITS volunteered to use the system for a few weeks. Suzanne Cadwell, Tech Support Specialist at ITS/UNC, and Dr. Dan Reed, CIO at ITS/UNC, both were able to use the system successfully during day-to-day work. They reported on their experiences through the ITS blog. In addition, an undergraduate student in Dr. Barreau's "Information Use for Organizational Effectiveness" class volunteered to use MyLifeBits to capture and access her classwork for several days. She was able to use MyLifeBits successfully as part of her class activities, and reported no major problems.

3.2.2 Participant observation

Overview

The pilot studies and the review of PIM research literature (see Chapter 2, "Conceptual Framework"), motivated the research questions and research design for this study. The research approach integrates two methods—*participant observation*, and a *technology probe*—in order to build a holistic understanding of students' personal information management behavior. These methods are drawn from well-established research practices in human-computer interaction and information science (J. Tang, Lin, Pierce, Whittaker, & Clemens, 2007). The research also draws upon experience gained from conducting ethnographic interviews and observation from previous research projects (Barreau et al., 2006), and the pilot studies.

The key goal of this component of the research was take a holistic approach that could help to build an understanding of student behavior grounded in actual contexts and situations. The direct observation and experience of PIM behaviors was intended to inspire new approaches to design.

This research was exploratory and focused on gaining a deep understanding of students' PIM behaviors, practices, and tools. This approach was inspired by Teevan, Alvarado, Ackerman, and Karger (2004), who write:

> Our findings are exploratory and observational, and as with many qualitatively-based studies, we seek only to analyze interesting phenomena, rather than to confirm existing theory. Accordingly, we present the incidents that emerged as particularly illustrative of the general patterns observed (p. 416).

Previous PIM research has primarily examined knowledge workers (e.g., managers and scientists) and used less-intensive research methods such as interviewing. This research therefore sought to extend and complement previous work by examining a different population and by studying PIM behavior using participant observation over an extended period of time. These novel aspects of the research design offered access to different types of observation and analyses that can extend PIM research and system design in new directions.

The ethnographic approach calls for "detailed, in-depth observation of people's behavior, beliefs, and preferences" (Boehner, Vertesi, Sengers, & Dourish, 2007; Hutchinson et al., 2003). Participant observation is needed to achieve this level of detail, because it involves "being in the presence of others on an ongoing basis and having some nominal status for them as someone who is part of their daily lives" (Glesne, 2005). It was decided that the most promising environment for establishing these relationships was a small, seminar-style class based on collaborative work.

Dr. Jean DeSaix's (Senior Lecturer in the Biology Department at UNC) honors general biology class (BIOL 101H, Tue/Thu 12:30 – 1:45) was identified as an appropriate class. BIOL 101H had four key characteristics that made it suitable for this research:

1. The class was relatively small, and organized as a seminar, with a high degree of student interaction.
2. The class enrolled students with a diverse set of interests.

3. The instructor was enthusiastic about my work.
4. The class material was at an introductory level, which enabled me to understand the readings and discussions so I could participate fully in the class.

Procedure

	Time period	Activities
1.	*Preparation phase* Before semester	Conduct pilot studies.
2.	*Introductory phase* First week of class	Meet with the instructor to interview her and prepare for the study. Attend the first class and introduce myself.
3.	*Research phase* During semester	Participate in all class activities, take field notes and collect artifacts.
4.	*Analysis phase* After semester	Analyze data.

During the preparation phase, pilot studies were conducted, and research questions developed. In the introductory phase, I met with Dr. DeSaix to clarify exactly what I would be doing and ensure that she was comfortable with my approach.

In the research phase (once the semester began), I attended classes regularly and participated fully in all activities, including:

- reading the textbook
- using the class and textbook websites
- taking notes
- completing in-class and homework assignments
- contributing to class discussion
- participating in group projects and presentations
- communicating with students using online tools (email, instant messaging, social networks)
- attending study groups
- taking tests and exams

I sought to construct alternative perspectives to my observations and analyses in two ways. First, I explicitly contrasted my own experience in the class versus the undergraduate students' experiences. Because I was about 10 years older than most of the students in the class, and had a more extensive background in PIM practices and technologies, my behaviors and reactions in the class were often quite different than theirs. Keeping track of and exploring these differences proved a fertile avenue for understanding problems and opportunities in PIM. In addition, I presented my observations and analyses to the instructor during our regular debriefing meetings. Her reflections on my thoughts helped provide alternative interpretations and implications of common student behaviors.

Instructors

BIO 101H was taught by Dr. Jean DeSaix, a Senior Lecturer in the Biology Department. Dr. DeSaix has been teaching BIO 101 for many years, and BIO 101H for about four years. She develops the curriculum and lectures for these classes and organizes the TA's who help run the class and its labs. Dr. DeSaix was highly enthusiastic about the research, as she has long been interested in applying technology to improve education. The class also had a Graduate Research Instructor, Geoffrey Reynolds[3]. The role of the Graduate Research Instructor was different from that of the typical teaching assistant. Geoffrey's job was to help students learn a specific topic (genomics) and to assist small groups of students in conducting a research project related to this topic. He did not regularly attend class, but came on scheduled days to give brief overviews of genomics research and tools, such as the HIV genomic database.

Students

The class initially enrolled 20 students. Over the course of the semester, four students dropped out of the class, leaving a total of 16. Of the remaining students, 10 were freshmen and six were sophomores; there were nine females and seven males. Students reported having selected or considered a variety of majors, including biology, biochemistry, biomedical engineering, economics, and

[3] This is a pseudonym.

linguistics. In addition, one student was visiting from another local university on a scholarship.

To facilitate future references to specific students, here is a complete listing of students, using pseudonyms:

1. Sarah	2. Esther	3. Mona	4. Paula
5. Melissa	6. Ned	7. Nora	8. Kelsey
9. Andy	10. Jason	11. Edward	12. Susan
13. Tain	14. Emma	15. Lena	

The pseudonyms reflect students' actual genders.

Researcher Involvement

During the first class, everyone in the class introduced him- or herself. Most students introduced themselves simply with their name, class standing (freshman, sophomore, etc.) and major or intended major. I introduced myself by explaining that I was a graduate student researching information use in biology education, and that I was trying to find ways to develop technology to make it easier for students to organize and manage their educational information. Students acknowledged that they accepted my participation as a class peer and also a research observer. Consistent with the objectives of my participant observation research, I attempted to keep my role as a researcher in the background. I concentrated on learning the material and interacting with students naturally during the course of class meetings and activities. I was also able to talk informally with students in the hallway and classroom in the slow times both before class began and after it ended.

Class Environment and Structure

The specific section of BIO 101H that I participated in was held in a small seminar room in Wilson Hall, at UNC-Chapel Hill. The room contained blackboards, an overhead slide projector, a digital projector, a TV with DVD players, and a computer. Students sat around a rectangular table, as well as in separate seats with fold-out writing desks, located around the edges of the room.

Class met on Tuesdays and Thursdays from 12:30 – 1:45pm, and included a total of 29 sessions for the Spring 2007 semester. I attended the class sessions along with regularly enrolled undergraduate students.

Figure 10. BIO 101H syllabus.

Spring 2007 **Biology 101H** [redacted]
12:30 – 2:00 TuTh

(Test dates are firm)

[redacted]

DATE			SUBJECT	READING (optional in parenthesis)
Th	Jan 11	1.	Introduction, Scientific Method	1
Tu	Jan 16	2.	Molecules	(2-4) 5
Th	Jan 18	3.	Cells (Begin West Nile Case)	6
Tu	Jan 23	4.	Transport	7, 8
Th	Jan 25	5.	Photosynthesis	10
Tu	Jan 30	6.	**TEST I**	
Th	Feb 1	7.	Carbon Footprint, Mitosis,	12
Tu	Feb 6	8.	Meiosis	13
Th	Feb 8	9.	Cycle gone wrong: cancer	19.3
Tu	Feb 13	10.	Understanding Inheritance	14
Th	Feb 15	11.	Chromosomal Inheritance	15
SUN FEB 18, 6PM SUPPER AT THE [redacted] HOUSE: group projects due				
Tu	Feb 20	12.	Molecular Genetics	16
Th	Feb 22	13.	Gene Expression	17
Tu	Feb 27	14.	**TEST II**	
Th	March 1	15.	Using Genetic Databases	25
Tu	March 6	16.	Viruses for good and ill: <u>Flu</u> due	18
Th	March 8	17.	Genomics	19, 20
			SPRING BREAK, MARCH 12-16	
Tu	March 20	18.	Molecular Basis of Evolution	19, 20
Th	March 22	19	Evolutionary Mechanisms	22, 23
Tu	March 27	20.	Speciation	24
Th	March 29	21.	**TEST III**	
Tu	April 3	22.	Bt Corn Case , Introduce Animal Physiology	38
Th	April 5	23.	Animal Reproduction	46, 47.1
Tu	April 10	24.	Hormonal Control of Reproduction	46
Th	April 12	25.	Work on Genomics Presentation	
Tu	April 17	26.	ECOLOGY <u>New Guinea Tapeworms</u> due	
Th	April 19	27.	Behavioral Ecology	51
SUN APRIL 22, 6PM SUPPER AT THE [redacted] HOUSE: Present Genomics				
Tu	April 24	28.	Population & Community Ecology	52.5, 52.6, 53
Th	April 26	29	Global Ecology	54
Tu	**May 3**	**4 pm**	**Final exam**	

The text is <u>Biology</u>, 7e by Campbell, and Reese & <u>Biological Inquiry</u> by Waterman and Stanley.
In this course, you will be working with a Graduate Research Consultant, [redacted] who will assist you in a genomics project. The GRC Program is sponsored by the Office of Undergraduate Research (www.unc.edu/depts/our).
In case of bad weather, class is canceled if city buses are canceled.

[redacted]

The class followed a structured syllabus (see Figure 10), closely tied to the textbook (*Biology*, by Neil Campbell and Jane Reece). Chapters in the textbook were assigned for each week. These chapters covered standard biology topics such as cell structure, meiosis, genetics, evolution, and ecology. Dr. DeSaix supplemented these readings with interactive lectures during class time. Her lectures concentrated on drawing out key points and synthesizing major ideas from the text. She used many slides, often providing illustrations beyond those in the textbook. She also included numerous personal stories and anecdotes. Taking advantage of the small size of the class, she encouraged students to ask questions throughout class. In addition, she regularly introduced in-class activities, such as solving a simple genetics problem. Also, some classes focused on discussing a supplementary reading (such as the book *Flu*, by Gina Kolata) rather than lecture. Dr. DeSaix also routinely assigned short tasks to be completed and then turned in to her in class (such as sketching part of meiosis on a sheet of paper).

The class had four exams. "Test I," "Test II," and "Test III" were taken during normal class sessions (and so lasted 75 minutes each). The final exam was scheduled separately and taken in a 3-hour session. While the exams were central to class grading, there were several other graded assignments (see Figure 11 for details). Grade weightings evolved over the course of the semester—in one class, for example, Dr. DeSaix showed the grading protocol on the projector and discussed changes to the weights with students as she made them.

Figure 11. Grading protocol for BIO 101H.

Grading Protocol for Biology 101 Honors [illegible] Spring 2007

45 %	**3 Tests**	**90 points**

Tests will be a combination of objective (multiple choice) and subjective questions.

Each test will be 30 points. In general, make-up tests will not be given. If one test is missed with official excuse, the other two will make up the total. If 2 are missed and excused, one will be made up by special arrangement. Tests will not be cumulative.

An estimated letter grade scale will be given for each test.

Grading mistakes must be discussed before the next test.

25%	**Final**	**40 points**

The final exam at 4pm on Tuesday December 12, will be worth 50 points, and will be cumulative

5%	**Group presentation**	**10 points (1st supper)**

Topics suggested by the class will be presented by groups. A group evaluation and a one page summary with references will be turned in.

10%	**Research Topic**	**20 points**

Each member of the class will have a topic for research for a 5 page paper and/or a 5 minute class presentation.

5%	**Book Reports**	**20 points**

Two books will be read during the semester and discussed by the class. Discussion points will be turned in.

5%	**Genomics project**	**10 points**

[illegible], our graduate research consultant will lead groups in asking questions of a gene database. Each group will develop a question and present their results to the class during the Oct 29 supper. Each groups should have a two page summary of findings, this may be as simples as a couple tables and could be prints of your PowerPoint presentations.

5%	**Class participation**	**10 points**

February 19, 2008 *5:35 PM* *gradingschemeSP07.doc*

In addition, Dr. DeSaix invited the entire class to her home on two occasions. The meetings at her home combined socializing, dinner, and time for presentation on a biology topic. Small groups were assigned to research and prepare presentations on particular topics. For the first project, students selected from a list of topics that the class had identified as interesting. For the second project, students worked on research questions related to HIV, developed by Geoffrey and Dr. DeSaix based on suggestions from the class. Each group developed a brief presentation which was delivered at Dr. DeSaix's house, after dinner.

Class Activities and Researcher Participation

In addition to attending class sessions, I also participated in group projects with students in the class. My participation was from the standpoint of a student enrolled in the class, and I involved myself in project work as fully as I could given the inherent limitations of my perspective as a graduate student researcher. I participated in three major collaborative projects:

1) *Group activity 1: Research and presentation on HIV vaccines*. For this project, each student selected from a list of topics that the class had identified as interesting. Teams were then formed based on the most popular topics selected. The assignment was to prepare a brief overview of this topic and present it to the class. My project team selected "HIV

vaccines" as our topic, and prepared on presentation that focused on why it has been so difficult to develop a vaccine for HIV.

2) *Group activity 2: Research and presentation on HIV genomics.* For this project, all of the teams focused on the same core topic—HIV genomics. Each team researched a different research question related to this topic. My project team focused on comparing changes in HIV strains in different regions of the world.

3) *Group activity 3: Research and presentation on biology in the community.* This group project required students to identify someone in the Triangle community who worked with biology, and then prepare a brief presentation giving an overview of their work. My team (which was just myself and Ned) selected Dr. Sharif Razzaque, who develops advanced laparoscopic surgery technology.

I also attended study sessions with students before exams. Before the first exam, Andy sent an email to the entire class asking if anyone was interested in getting together to study. A group of six students gathered in the Student Union to study informally. Before the second exam, Andy and I emailed back and forth, and then we both sent emails to the class suggesting study times and locations. A few students expressed interest, but ultimately only Andy and I showed up. We wound up studying in a room in Davis Library.

Beyond these collaborative activities, I also prepared on my own by reading the textbook and casebook, and reviewing online resources (primarily the textbook's website). I attempted to prepare for class and exams as a typical student would. Because of my additional responsibilities as a graduate student, though, I may have spent less time reading and reviewing material than most undergraduate students in the class did.

Overall, by participating in class activities and projects, interacting regularly with students, and working with class materials and assignments, I was able to gather a broad array of data on how students manage their personal educational information.

Types of information

As part of my research, I observed and categorized a wide variety of types of information that students captured and managed. Figure 12 provides a summary taxonomy of the major types of information (and supporting technologies) that students managed in BIO 101H. I developed this taxonomy based on my observations of how information was being sought, retrieved, and managed in BIO 101H. This summary provides a sense of the scope and variety of information inputs within a single educational context (one class, within one domain). This summary is not intended to be comprehensive, but only to demonstrate that students were observed collecting and managing a diverse array of information using many different media and formats.

Figure 12. Taxonomy of information types observed being captured and managed in BIO 101H.

- □ Analog
    - o planners/diaries
    - o handwritten notes

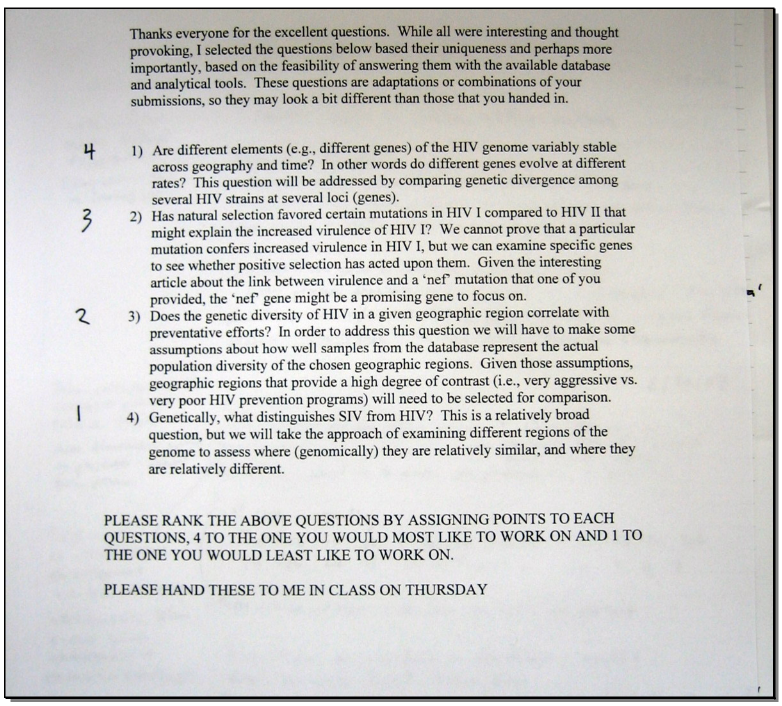
  - typed handouts
  - drawings (e.g., salamander cells in mitosis)
  - data/tables (e.g., Punnet Square genetics analyses)
  - books (and accompanying notes/annotations)
  - print articles (e.g., articles found during research for class assignment, or referenced on textbook website)
  - chalkboard/whiteboard
- □ Digital
  - typed notes
  - typed assignments (e.g. summary of group project)
  - email
    - student to student, individual
    - student to small group of students (project group)
    - student to whole class (e.g., Blackboard broadcast email)
      - organize a study group for exam
    - instructor to whole class
    - instructor to student/student to instructor
  - Word documents
    - created in class (e.g., during in-class assignment)
    - created for group project
    - downloaded from Blackboard (created by instructor or TA)
  - PowerPoint presentations
    - viewed in class
    - downloaded from Blackboard (created by instructor or TA—may contain different slides than the version seen in class)
    - created for group project, then posted to Blackboard
  - Web pages
    - viewed in class to pursue some topic mentioned in class in greater depth
    - on Blackboard—announcements, etc.
    - shared by classmates through email or MyLifeBits as part of a group project
  - interactive

            - interactive Web activities and quizzes/tests on textbook site
        - social network-based information
            - Facebook connections and messages
        - multimedia
            - Video
                - DVD of research on cancer cells
                - Video clips from Discovery Channel on textbook site
            - Audio
                - MP3 audio on textbook site
            - Animations
                - Activities and animated illustrations on textbook Website/CD
- □ Cognitive
    - Memory for in-class lectures and discussions
        - "audio"—instructor's speech, students' speech
        - physical movement, e.g. instructor using her arms, body, face to make a physical analogy to a biological concept

The following images represent examples of key information artifacts collected during the fieldwork.

Figure 13 shows a printed assignment that was handed out to students during a class session. This fact that this assignment was delivered in paper-based form, indicates a continuing prevalence and importance for paper-based information in undergraduate education. This practice is, obviously, dependent on teacher dissemination activities, but the scenario captured here is worth noting, given that this paper-handout was part of a class that was ostensibly organized around digital systems such as Blackboard. This assignment required students to process the paper handout, organize it in their PIM system, remember to complete the embedded assignment by the due date ("Thursday"), and then refind the document at the next class session so they could hand it in for evaluation.

Figure 13. Paper handout from BIO 101H.


Thanks everyone for the excellent questions. While all were interesting and thought provoking, I selected the questions below based their uniqueness and perhaps more importantly, based on the feasibility of answering them with the available database and analytical tools. These questions are adaptations or combinations of your submissions, so they may look a bit different than those that you handed in.

4 1) Are different elements (e.g., different genes) of the HIV genome variably stable across geography and time? In other words do different genes evolve at different rates? This question will be addressed by comparing genetic divergence among several HIV strains at several loci (genes).

3 2) Has natural selection favored certain mutations in HIV I compared to HIV II that might explain the increased virulence of HIV I? We cannot prove that a particular mutation confers increased virulence in HIV I, but we can examine specific genes to see whether positive selection has acted upon them. Given the interesting article about the link between virulence and a 'nef' mutation that one of you provided, the 'nef' gene might be a promising gene to focus on.

2 3) Does the genetic diversity of HIV in a given geographic region correlate with preventative efforts? In order to address this question we will have to make some assumptions about how well samples from the database represent the actual population diversity of the chosen geographic regions. Given those assumptions, geographic regions that provide a high degree of contrast (i.e., very aggressive vs. very poor HIV prevention programs) will need to be selected for comparison.

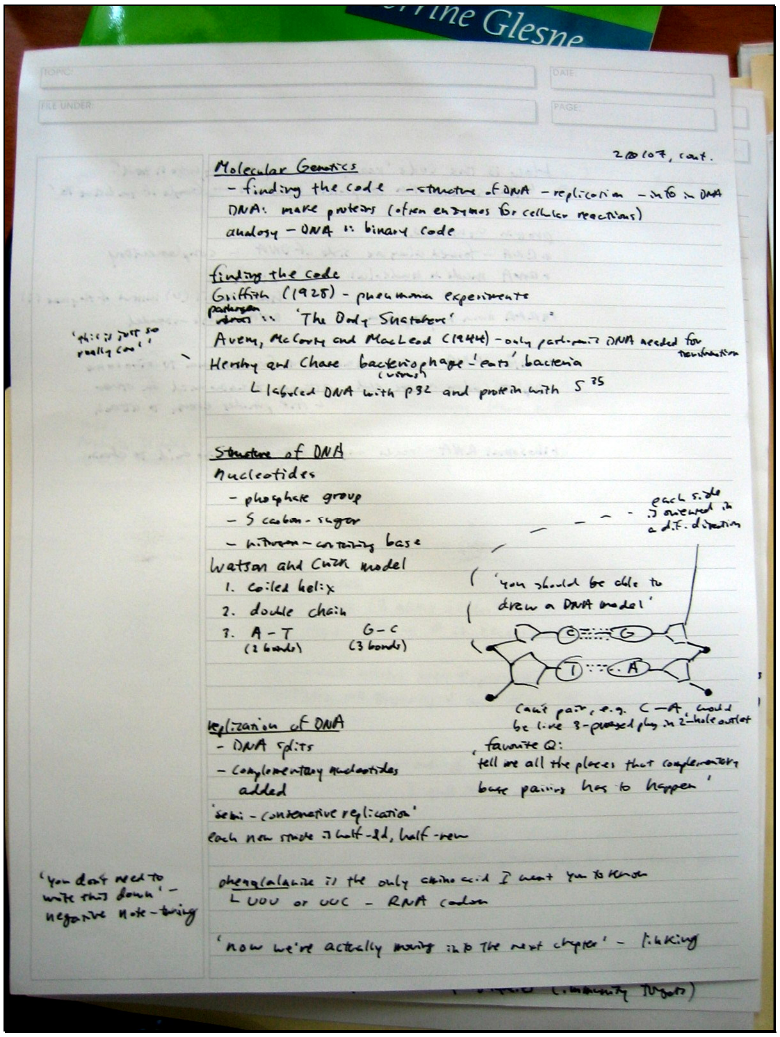
1 4) Genetically, what distinguishes SIV from HIV? This is a relatively broad question, but we will take the approach of examining different regions of the genome to assess where (genomically) they are relatively similar, and where they are relatively different.

PLEASE RANK THE ABOVE QUESTIONS BY ASSIGNING POINTS TO EACH QUESTIONS, 4 TO THE ONE YOU WOULD MOST LIKE TO WORK ON AND 1 TO THE ONE YOU WOULD LEAST LIKE TO WORK ON.

PLEASE HAND THESE TO ME IN CLASS ON THURSDAY

Figure 14 shows an example of handwritten class notes from the researcher's participation in a class session. The notes illustrate some of the complexity and affordances of pen-and-paper notetaking. Paper notes can flow freely across the page in a way that is difficult to replicate with word processors. Diagrams or models can be quickly sketched in the same space as textual notes. Marginal annotations can be added without disturbing the layout and organization of the notes.

Figure 14. Researcher's handwritten class notes from BIO 101H class.



Blackboard is a "learning management system" that offers capabilities including communication and scheduling. In BIO 101H, Blackboard was used primarily as a document repository. Figure 15 illustrates organization and presentation of documents on the class Blackboard website. The figure shows that files in a range of different application formats (such as Microsoft Word, Excel, and PowerPoint; Adobe Acrobat) were posted to the site for students to access. As shown in this screenshot, the files were presented in a simple list, without discernible organization or structure, other than by date posted. The files on Blackboard were not automatically integrated in any way with student's own PIM systems, such as their Windows file system and email, although students were able to manually download files from Blackboard and store them in their own file systems.

Figure 15. Documents on BIO 101H Blackboard site.

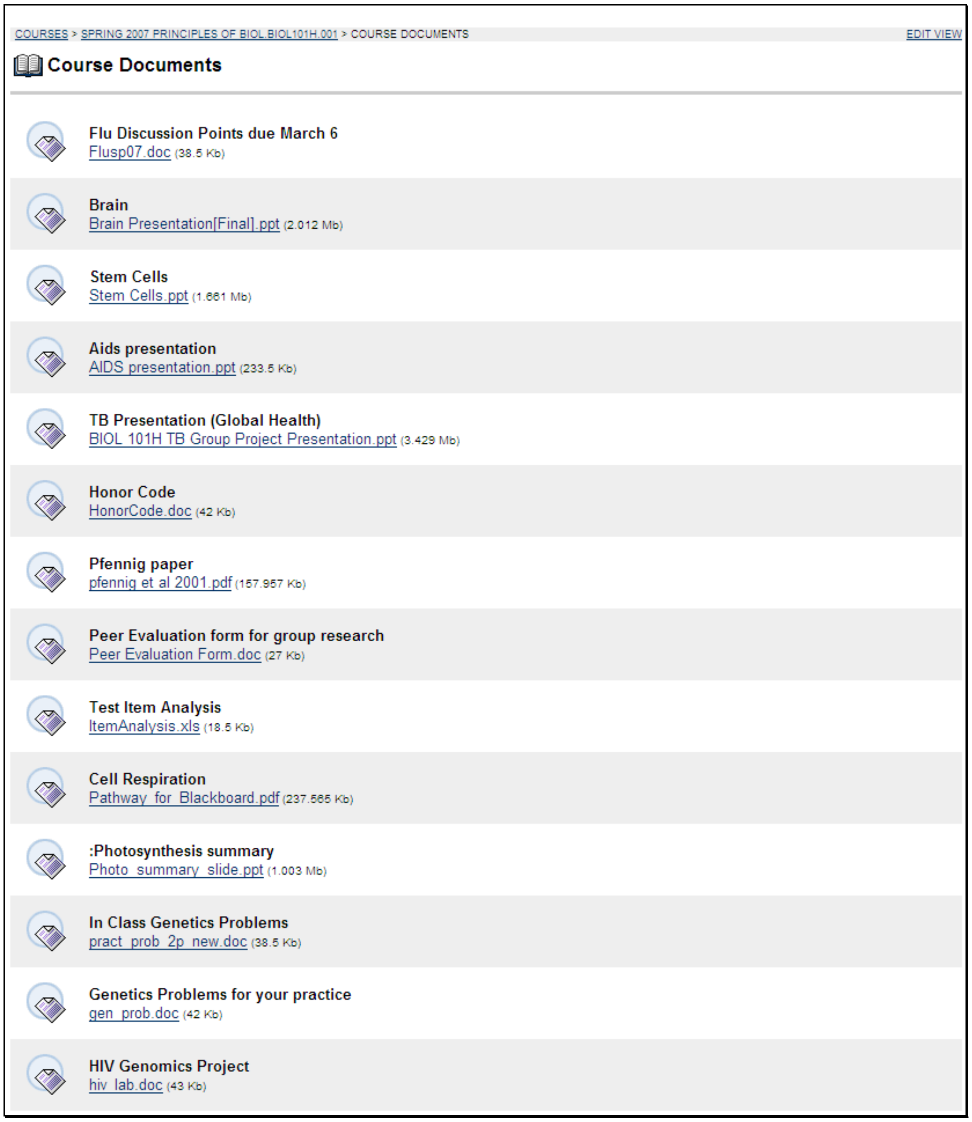


Figure 16 illustrates the companion website to the textbook (*Biology*, by Campbell and Reece). The textbook website provided a variety of resources and activities for each chapter, including quizzes, investigations, animations, audio, and videos. These resources were quite extensive, and also were not integrated with other class resources such as Blackboard. For example, there was information on the textbook website that was relevant to the group project on

HIV genomics, but was not connected in any way to Blackboard or the class syllabus.

Figure 16. Campbell biology textbook website.

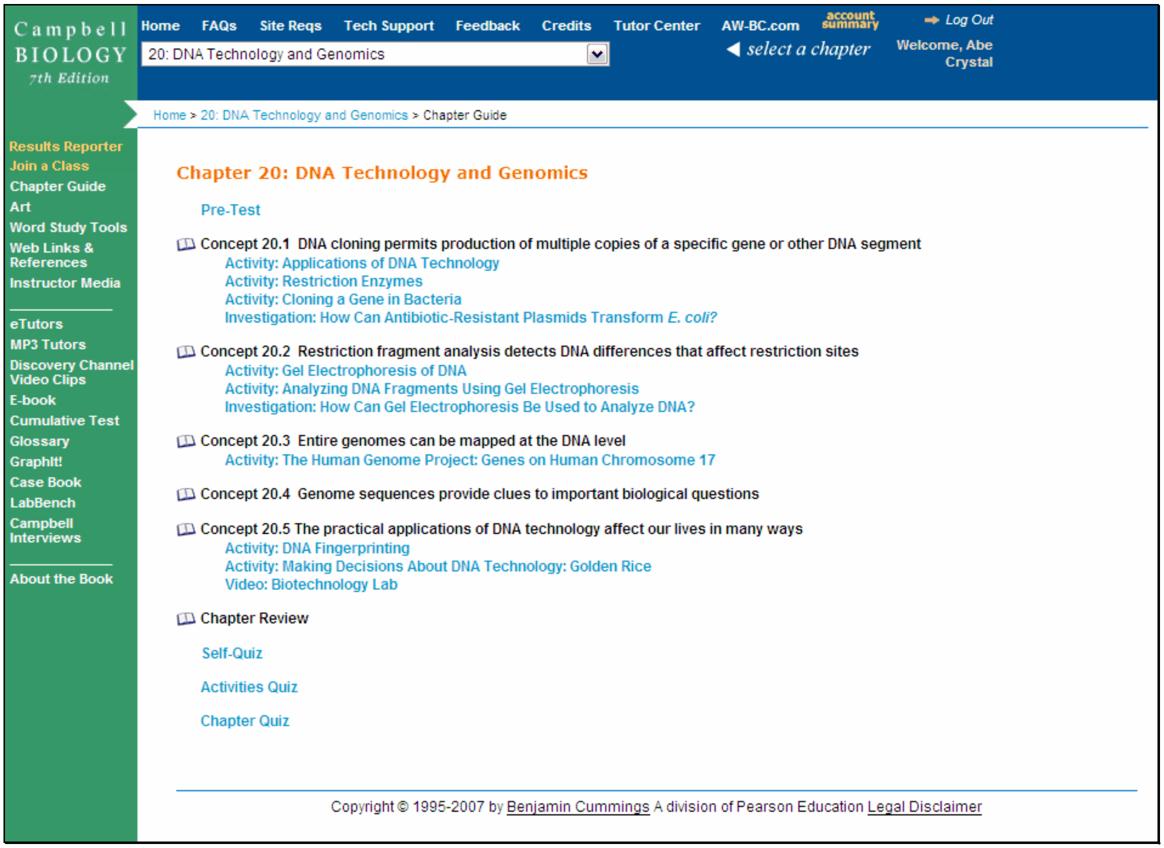
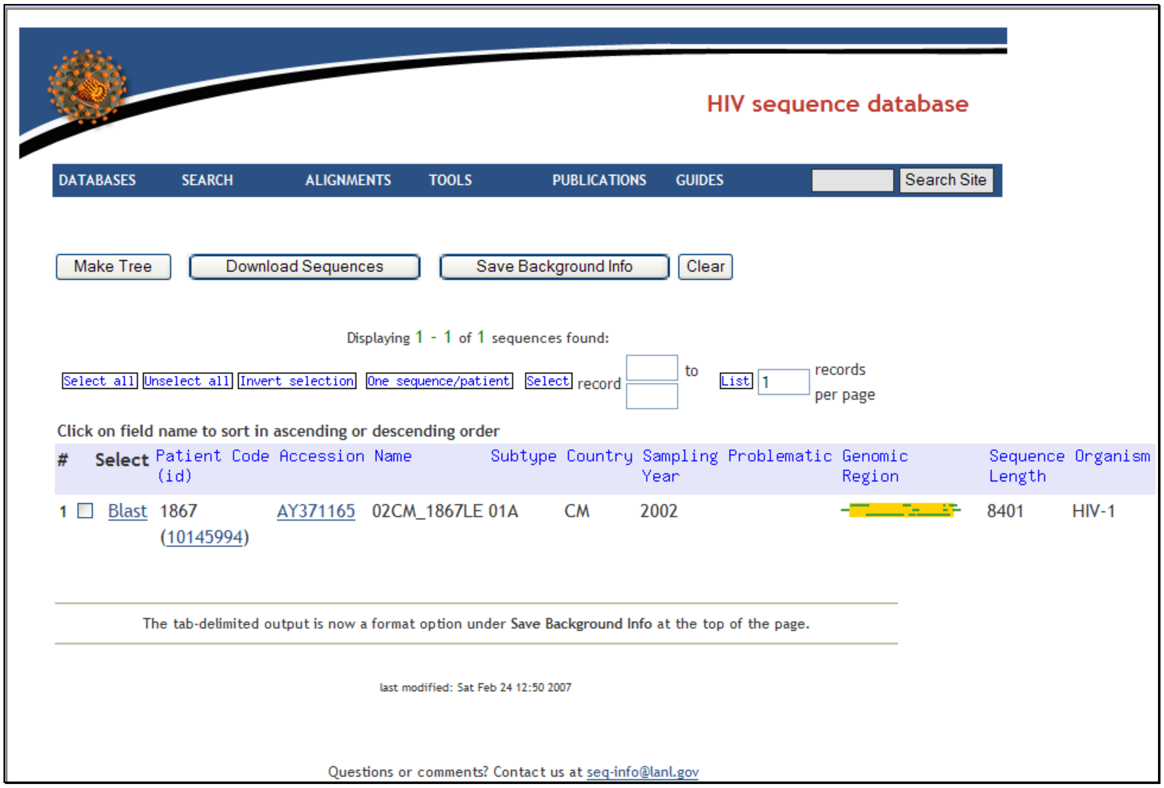


Figure 17 shows a screenshot of the HIV sequence database, which students were required to use as part of the HIV genomics group project. Geoffrey, the Graduate Research Instructor, gave an overview of the database and was available to answer questions about how to use it. This artifact illustrates how dynamic applications such as databases and search tools were an important component of even an introductory class such as BIO 101H.

Figure 17. HIV sequence database, introduced by Geoffrey (graduate instructor) in BIO 101H.



PIM tasks in the field study

This research focuses on four primary tasks that PIM can support (see Table 9 for a summary of these tasks, and Chapter 2, "Conceptual framework" for a detailed discussion.). These tasks are derived from previous research on PIM practices (Barreau & Nardi, 1995; Capra, 2006; Kirsh, 2005; Marshall, 1998).

Table 9. Summary of four primary PIM tasks.

Refinding. Accessing information that one has acquired and stored in a PIM system (such as an email to a colleague, a report downloaded from a Web site, or a picture from a friend's wedding).
Reminding and task management. Keeping track of what projects and tasks one needs to work on, including key deadlines.
Making order. Filing or organizing as practices that help make sense of a complex stream of incoming data.
Reflection and metacognition. Improving metacognition, the "activities and skills related to planning, monitoring, evaluating, and repairing performance" (Ericsson, 2007), p.148. Reflecting on one's activities to understand them more deeply, and construct personal narratives.

REFINDING

Students were observed to refind information during class-related activities, including class discussions, research assignments, group projects, and studying for exams. Specific refinding activities that were observed included browsing through email messages using a webmail client, opening Word and PowerPoint files stored on Blackboard, using Google Desktop to search through files on a laptop, reviewing paper notes, and reviewing digital notes.

Reminding And Task Management

Students in BIO 101H had many different assignments and deadlines, involving both individual and collaborative work. Overall, students were required to manage a complex array of constantly evolving tasks, deadlines, and reminders. In BIO 101H, these tasks included:

- reading
  - read certain chapters and sections in the textbook
  - read a certain case in the casebook
  - read a book
  - read a handout provided in class
  - read a Web site mentioned in class
- research
  - find information about a specific topic assigned in class
  - complete an analysis or calculation about a specific topic assigned in class
  - find a person in the community who works on a biology-related topic
- visualization
  - sketch or model a biological process discussed in class
  - create slides to illustrate a topic assigned to a project group
- analysis/writing
  - summarize the key points from an assigned book reading
  - prepare a report based on research into an assigned topic
- speaking
  - prepare a 5-minute group presentation on an assigned topic

Many of these tasks had associated deadlines such as "March 12th" or "due by the next class." In addition, students managed tasks and reminders for other classes, extracurricular activities, and their personal lives. The focus of this research was on how they managed tasks and reminders for BIO 101H.

Students were observed to use general-purpose tools, such as planners and notebooks, for task management. Students were not observed creating or referring to detailed lists of projects or tasks, such as a "to-do list". Rather, task management was embedded in other information stores and activities. All students in the class were observed to use some form of paper notebook or binder to store tasks and reminders. The specific form and function of these physical tools, however, were highly individual. While many students used 3-ring binders, other tools seen in class included a small (3½ x 5½ inch) Moleskine notebook, 8 ½ x 11 inch wire-ring notebooks, and file folders.

Students referred frequently to class resources, including the Blackboard announcements page and the online syllabus (a Word document hosted on Blackboard). In addition, students routinely used email reminders, both from the instructor and from their peers, to keep track of tasks and due dates. For example, Dr. DeSaix sent the following email:

> I will be in my office in 302 Coker today, Wednesday, from about 2:30-4:30. Feel free to stop by with any questions.
>
> For the class after the test, please prepare part I of the Corn Under Construction case study.

This email reminded students of the next test, and reminded them to prepare for an upcoming class by reading and completing a specific case study in the class casebook. This reminder reiterated previous indications (such as an oral announcement in class, and a notation on the syllabus) that students needed to complete this case study.

Students regularly discussed upcoming assignments and due dates during conversations among themselves. These conversations complemented students' personal task management and reminding systems by enabling them to understand their peers' perspectives. Students were able to gather information about tasks, and be reminded of upcoming due dates, during these conversations—particularly at the beginning of class, when Dr. DeSaix would often clarify her expectations about deliverables. Students also used their memories as a component of their task management and reminding system.

Making Order

Students were rarely observed to engage in activities explicitly focused on making order within their PIM systems. Instead, making order behavior was inferred from observations of students' browsing and refinding behaviors. For example, during one project group meeting Melissa was observed to browse through her email archive using the UNC Webmail interface. She seemed to rely on the default organization method in her archive, as she appeared not to have created folders for categorizing messages. Instead she browsed through her entire archive of messages chronologically, looking for criteria indicating that a particular message was relevant to her needs. Dr. DeSaix and Geoffrey also contributed to making order, as they controlled (through their administrator accounts) the content and labels of messages and documents posted to Blackboard. As shown in Figure 15, above, Dr. DeSaix and Geoffrey also appeared to rely on the default organization method when using Blackboard, as no discernible organization system other than a reverse chronological approach was observed.

Metacognition And Reflection

Attempts at metacognition were observed during class sessions. For example, Dr. DeSaix prompted students to rethink a potentially confusing idea that was just introduced—in one class she said, "did ya'll make sense out of that last part? ... I'll say it again." In other cases, she emphasized the need for students to reflect on a particular idea or reading. When discussing the co-evolution of plants and pollinators using the class casebook, Dr. DeSaix specifically invoked reflection by saying "this is one of those things I want you to jot down and think about it."

Another technique used for eliciting metacognition was an "item analysis" for exams. The item analysis is a form that students fill out when asking for help or clarification on an exam question they answered incorrectly. This activity asks students to explain why they think they didn't get the question right, and identify a root cause such as "it was in my notes, but I didn't understand it."

An alternative approach Dr. DeSaix used was to encourage students to participate in reflective thinking and discussion with their peers. In response to a student's question about what to study for a particular topic, Dr. DeSaix said, "as long as you can explain it to somebody else, you'll be in good shape." During another class, when reviewing the results of a test, Dr. DeSaix said, "everyone in class missed the question on genomic imprinting." This statement potentially provided a basis for students to reflect on the topic of genomic imprinting.

Attempts at metacognition were also observed outside of class, often motivated by class assignments and exams. Study sessions provided one venue for students to have metacognitive experiences as they attempted to assess how well they were prepared for an upcoming exam. Students were observed using a mix of both "strategic" and "topical" metacognition. *Strategic* metacognition involved thinking and talking about what to expect on the exam, what types of questions might be asked, and what topics were best to focus on (e.g., "Do we need to know the four levels of protein structure?"). *Topical* metacognition involved specific content questions (e.g., "What's the difference between anabolic and exergonic?").

Data Validity and Credibility

Data were gathered via observations conducted during each class session and out-of-class interactions with students. This approach was based on design research techniques, particularly HCI research efforts that use immersion in a field setting and qualitative data analysis to inform system design (Drucker, 2002). I attended a total of 29 class sessions, each of which lasted 1.5 hours. In addition, I spent approximately 5 – 10 hours per week in out-of-class activities such as meeting with a project group, attending study sessions, and communicating online with students. Overall, the fieldwork encompassed roughly 150 hours of direct participant observation with students. Written field notes of observations from class sessions and meetings with student notes were typically in the range of 300 – 500 words and included 3 – 8 distinct observations about student behavior. The complete record of notes and analyses for the study included approximately 20,000 words in 46 entries. This record was also posted to the dissertation blog, and made accessible to researchers who could offer feedback on the results.

This research employed three primary approaches for ensuring the credibility and validity of results: *sampling*, *research technique*, and *verification* (Bellotti et al., 2005; Bergman et al., 2006).

As stated above, the class included a sample of students with an array of different interests and majors (and even one student from a different university). This sample was broader and diverse than would be found in a more specialized class that enrolled students from only one major.

Three elements of research technique, recommended by qualitative methodologists (Barreau, 1995) were used. First, I explained my role as a participant observer, so that participants could understand why I was conducting the study, and that they were not being evaluated or judged. Second, I remained in the setting for an extended period of time (four months), so participants could become comfortable with my presence. Third, I was able to participate in and observe many situations in which participants were directly engaged in tasks, which is when people lose self-consciousness and anxiety.

Finally, I triangulated key findings from the fieldwork with "parallel measures" in order to help establish the representativeness and validity of the findings. I compared ideas I developed through in-class observation and my own experience with artifacts from the class, such as emails from students. For example, an email from Andy expressing confusion over an assignment related to the *Flu* book served as a parallel measure of the confusion I had already observed in class.

I conducted "member checks" by discussing ideas developed during the research directly with participants. For example, I was able to raise some of the issues I observed with Blackboard usage during informal conversations with my project groups. In addition, the participatory design session served as an opportunity for exploring and validating ideas directly with students. I further triangulated the ideas I developed with the instructor's perspective on student behavior by conducting multiple in-depth interviews with Dr. DeSaix.

3.2.3 Technology Probe

To complement the participant observation research I designed a technology probe study. I refer to this as a "technology probe" approach because the technology is being used to probe students' practices and understandings of PIM (Chi, 2003). During the same semester, I recruited students to use MyLifeBits system on their personal laptops to manage their digital information (such as emails, files, saved Web pages, etc.). The goal of this study was to explore students' use of MyLifeBits in typical educational tasks and situations.

Sample

Students enrolled in the BIO 101H class were recruited for this part of the study. Prior to recruitment, they were shown a demonstration of MyLifeBits in class. An e-mail message requesting volunteers to use the system was then sent to all members of the class. Participants were offered a $50 gift certificate and upgraded RAM as compensation for their time. Eight students responded to my request for volunteers. Of these, one declined to participate after learning further details about the study.

Technical problems prevented MyLifeBits from operating properly on three of the participants' computers. One student was running Windows Vista which proved to be incompatible with MyLifeBits. One student had a non-CCI computer or which was simply not powerful enough to run the software adequately. One student's computer could not run the required web server software due to a configuration problem. Two of the students who had technical problems remained in the study as a "control group." I was able to discuss with them their natural use of PIM software such as e-mail clients and Microsoft OneNote.

Procedure

I met with each of the seven volunteer students individually to install MyLifeBits on their personal laptop computers. Before installation, participants signed an informed consent agreement. After installing the software, I gave participants' a brief walk through of MyLifeBits' functions, and made sure they felt comfortable using all of its features. For students who had 1 GB or less of memory installed, I obtained an additional gigabyte of RAM and had it installed in their laptop. Participants then continued to use MyLifeBits for the remainder of the semester and exam period. Overall, the technology probe lasted from six to eight weeks depending on when I met with the participant to install the software.

After the semester, all of the participants (including the control group) met with me for a two-hour participatory design session in a small classroom with whiteboards and drawing materials. The motivation for this "participatory design" was to involve students in envisioning what future student-centered PIM systems might look like. The participatory design session took the form of interactive focus group, in which students participated in exercises and group discussions to create ideas for PIM systems. Students were asked to identify key tasks and scenarios, and then develop prototype designs. Students participated in the following specific exercises to stimulate discussion:

- **Exercise 1:**

  Interview another student about his or her PIM practices, using these questions:

  - How do you keep track of important Web pages?
  - How about important emails?
  - How do you organize files on your PC (like documents, spreadsheets, presentations, etc.)?
  - How do you keep track of tasks and due dates for class?
  - How do assess how much you've learned for a class (how prepared you are, whether you need to study more, etc.)?

- **Exercise 2:**

  As a group, brainstorm some specific scenarios for how a student could manage information, related to each of the areas you covered in the interview.

- **Exercise 3:**

  Based on the ideas we have discussed, work with a partner to sketch out ideas for technologies that could help solve one of the specific problems we identified. Then, switch partners and discuss your ideas.

I then reviewed and summarized the ideas generated as a result of these exercises, which helped inform my own design concepts. The specific ideas proposed by students are presented in the Results section.

At the conclusion of the semester's exam period, I met with each participant to interview him or her, and collect log data and screenshots from MyLifeBits. I then removed MyLifeBits from the participant's computer.

Data collection

I investigated students' use of MyLifeBits in four ways. First, I used informal opportunities (e.g., the time before class began) to discuss with students their use and impressions of MyLifeBits. I summarized these discussions in my daily field notes. Second, I sent periodic e-mails to all the participants with questions about MyLifeBits and example ways to use it. Third, I set up individual interviews with all participants to discuss their PIM practices and use of MyLifeBits in greater detail. The interviews were guided by reviews of the captured materials in their MyLifeBits archives. Fourth, I collected usage logs from each MyLifeBits database at the end of the semester. Taken together, these activities allowed for multifaceted evaluation of the system, including both usability (ease of learning and using the system and interface) and usefulness (ability of the system to support students' learning and PIM practices).

Chapter 4: Results

4.1 Research Question 1: Ethnographic field study of undergraduate students' PIM behaviors and practices

4.1.1 Data analysis

The field data were analyzed using an inductive coding process, motivated by *grounded theory* (Hignett, 2005; Ireland, 2003; Maxwell, 2005; Merriam, 1998b; Pressley et al., 1998; Schwartz & Jacob, 1979). Grounded theory is a widely-used method for analyzing qualitative data. It "emphasises the fit between data and the emerging theory, rather than moving deductively down from a prior hypothesis" (Singh & Bartolo, 2005, p. 91). This approach was chosen because of its compatibility with the *design research* approach. As Sasse (1997) notes, "Grounded theory… offers a framework for deriving theories from observations which exactly fits HCI's requirements, without imposing the constraints of the traditional science approach" (p. 52). This technique was selected specifically because of the exploratory and conceptual nature of the research.

The field data were structured and refined through an inductive and "progressive process of sorting and defining and defining and sorting" (Glesne, 2005). The goal of this process was to identify key concepts and central ideas which could inform both my investigation of the research questions and motivate the creation of innovative design concepts. The first step in this process was to undertake bottom-up analysis of the field data. Collected field data (including raw field notes, the research blog, interview transcripts, photographs, documents, screenshots, and so forth) and analytic memos were reviewed. During this analysis issues were identified and observations relevant to the research questions were noted. Using techniques from affinity diagramming and requirements definition (Courage & Baxter, 2005), I then clustered the issues into groups, and refined the groups into a high-level framework of observed themes. Thirteen key ideas and themes were identified (see Table 10).

Table 10. Initial thematic framework based on inductive analysis of the field data.

1.	Peer learning
2.	Project management
3.	Emotion/affect
4.	Reflection
5.	Shared awareness/gaps
6.	Collaboration
7.	Social IA/PIM
8.	Priority and relevance
9.	PIM as a learnable skill
10.	Narrative
11.	Reminding
12.	Dynamic, evolving task management
13.	Information architectures for PIM, e.g. the FAQ as model

Three independent analysts (doctoral students from the School of Information and Library Science) reviewed the field notes and assessed the validity of the thematic framework. Analyst 1 stated that “For the most part, they [the themes] all seem to ‘fit.’” Analyst 2 concluded that “I'm sure you would be fine sticking with your conceptualization of the themes… They are comprehensive and mostly quite distinct." Analyst 3 agreed, and observed that "They [the field notes] reminded me of my experience of taking classes with undergraduate students," suggesting the veridicality of the field observations and thematic analysis. Overall, the analysts confirmed the usefulness and validity of the main themes. The independent analysts also identified the following specific issues with the thematic framework:

- Some themes appeared less widespread and pertinent in the field data than did others.
- The issue of how cultural and institutional authority influenced student behavior was not sufficiently addressed.
- The importance of students' information sharing in group/collaborative contexts was not discussed sufficiently.

The thematic framework was revised by merging, renaming, and clarifying the scope and definition of the themes, based on feedback from the independent analysts. After revision, the framework contained a final set of eight themes. The revised set of themes served as a framework for further interpretation and presentation of the findings from the fieldwork, and assessment of their implications for design. Three higher-level groups were also created to provide an overarching structure for the themes: task/projects, content/learning, and information access.

The final set of themes used for analysis are presented in Table 11.

Table 11. Final thematic framework used in analysis.

		Theme	Definition
TASKS / PROJECTS	1.	Project management.	*The act of defining, overseeing and following through on activities, such as conducting research, creating presentations, or drafting documents.* In this study, students were observed to engage in project management, due to the length and complexity of class assignments, the requirements for collaborative work, and the need to identify and integrate many information sources.
	2.	Collaboration	*The combined work of two or more student to complete class-related projects.* Collaboration was a fact of life for students, and was seen to be a major influence on their PIM behavior. Often students did not explicitly capture or index important information—instead they relied on their collaborators to provide information, remind them of tasks, and so forth.
	3.	Dynamic, evolving task management	*The process of directing or conducting educational work in a fluid, rapidly-changing environment.* Students often coped with assigned tasks that were highly dynamic, constantly evolving, and ambiguous. The dynamic, evolving nature of tasks often made it difficult for students to develop a coherent inventory of all of their tasks and associated deadlines.
	4.	Shared awareness/gaps	*The challenges inherent in developing a common understanding of class structure, assignments, readings, and progress so as to make progress toward educational objectives.* Students were observed to have difficulty developing a shared awareness of what others (peers, instructor, students) knew, understood, and felt. Gaps occurred regularly, leading to stress, low-quality work, and reduced learning.
CONTENT / LEARNING	5.	Affect and narrative	*The influence of narrative (including the power to capture attention and structure memory) as well as affective responses and processing on PIM behaviors.* In this study, emotional references during class sessions captured students' attention and interest, and generated discussion—they appeared to encourage active learning.

	6.	Learning PIM	*The process of discovering, adopting, and improving PIM practices and technologies.* Although students in this study were generally comfortable with technology, there was a large variance in both and PIM and technology-related expertise and knowledge. This variance indicates that some students have learned PIM skills through experience or study.
INFORMATION ACCESS	7.	Social information management	*Conducting PIM activities (such as capturing, organizing, and refinding information) via social networks or connections.* Students were observed to rely on social connections as an integral part of their PIM activities—but reliance on peer knowledge often proved a double-edged sword. Working with peers to explore concepts and question each other's understanding was a key metacognitive strategy for students, but such social metacognition was often difficult to initiate.
INFORMATION ACCESS	8.	Priority and relevance	*The task of identifying which information is most important and relevant to learning and educational objectives.* Identifying relevant, high-priority information is critical to academic success. Students' PIM systems, however, often provided little support for these concepts of priority and relevance.

I also examined the data from the perspective of my central analytical framework, the four core PIM tasks (refinding, reminding and task management, making order, and reflection and metacognition). I compared findings from the fieldwork that were relevant to the PIM tasks with the overarching themes, so as to draw greater insight into both tasks and themes.

Finally, I selected specific cases from my fieldwork that demonstrate some of the key insights that emerged from my observations of how students cope with PIM in today's technological and educational environment. It is useful to distinguish two types of cases presented in the results that follow: representative and illustrative. "Representative" cases exemplify *key insights* into participants' PIM behavior. These cases are snapshots of activities that were observed multiple times (e.g., observations related to the idea of "dynamic, evolving task management" appear roughly twenty times in the course of my field notes) and validated through triangulation with interviews and artifacts. The observations presented below are intended to provide concrete instances that can support PIM design and research efforts in a different way than the abstract themes can.

In addition, "illustrative" cases exemplify *emerging issues* in participants' PIM behavior. These observations were selected because they appeared provocative or insightful, and so can encourage new approaches to PIM research and design. They were not as widespread or carefully validated as the observations classified as "representative."

These observations link the thematic framework to opportunities for research and design related to the core PIM tasks. The thematic analysis is organized into eight subsections representing the eight key themes (see Table 11, above), and is presented in "Field study results: PIM issues and strategies," below.

4.1.2 Field study results: PIM issues and strategies

This section presents the discovered set of themes identified in the analysis of the field data (see "Data analysis," above, for details of how the themes were identified and verified). Each theme is presented as a summary description, followed by both representative and illustrative cases from the field which bear on the theme. To reiterate, “representative” cases provide examples of key insights into widespread PIM behaviors and practices, while “illustrative” cases provide concrete instances of emerging issues in participants' PIM behavior.

The implications of each theme for PIM research and system design are examined further in Chapter 5, “Discussion.”

Theme 1: Project Management

Overview

Students were observed to take on project management responsibilities, which motivated and structured their PIM systems and behavior. Students were responsible for understanding and managing components of projects, including *scope*, *deadlines*, *deliverables*, *coordination of responsibility*, and *integration of individual efforts*. Students engaged in many tasks that required project management, such as “keeping up with the textbook reading,” “preparing information for a discussion of a case study,” “research and preparing a presentation about brain structure,” and “studying for the second exam.”

Project *scope* involved determining the overall requirements and scale of a project, as well as the resources that would be needed to complete the project. Project *deadlines* were specific dates on which project deliverables were expected to be completed and submitted (e.g., a presentation delivered, or a report handed to the instructor). Project *deliverables* included... *Coordination of responsibility* refers to the need to determine which project team members would contribute to various components of the project, and by when they would complete their work. Finally, *integration of individual efforts* refers to the work of bringing together contributions from multiple individuals to create coherent project deliverables.

Project management intersected with personal information management as students sought to find and organize project information. This task encompassed both information about the project itself (such as deadlines and meeting times), and information about the biology topic addressed by the project (such as the challenge of creating a vaccine for HIV). Students' project management activities involved many different components of their PIM systems, such as paper notes, planners, emails, and Blackboard. Project-related actions were observed to be embedded in paper notes, emails, and Blackboard announcements, thereby requiring students to process these inputs, determine the implications for their project work, and keep track of the resulting deliverables and deadlines.

Representative strategies observed for project management included: sending emails to members of a project group to ask for information or set up a meeting; holding check-in conversations before and after class; and using deadlines to motivate other group members to meet or complete a task.

Representative Cases

Case 1.1: Project management through email and Blackboard

Students used class information systems—particularly Blackboard and email—to identify project requirements and deadlines. Project tasks, along with supporting information and deadlines, could be embedded in these systems. Below is an example email from Dr. DeSaix that elicited project management behavior:

> The Genomics questions are under "Assignments" for you to rank for Thursday.
>
> I still need powerpoints from 2 groups.
>
> Test will have 20 multiple choice and 10 points of free-response questions.
>
> See you Thursday

This email includes the embedded task "I still need powerpoints from 2 groups," which was related to the project "deliver a presentation on a selected biology topic to the class." Project teams were required to submit their completed PowerPoint slides to Dr. DeSaix so that she could post them to Blackboard, and other students could review the slides in preparation for the second exam. This email required students to complete multiple project management tasks:

1. Understand the *deliverable* based on the cue "I still need powerpoints from 2 groups," and Dr. DeSaix's previous statements.
2. Determine the implied *deadline* (before the exam).
3. *Coordinate responsibility* of submitting the completed slides to Dr. DeSaix.

Illustrative Cases

Case 1.2: Breakdown in project management

One day, Dr. DeSaix asked the class to turn in our project descriptions for our final class project. Ned and I were working together on this project. We did not realize that a project description was due on this day, so we hadn't prepared anything. We spoke with Dr. DeSaix after class, and she asked us to go ahead and turn something in. Ned wrote up a brief description of our project on a sheet of notebook paper. Later, we realized that this description had gotten lost between when we discussed it with Dr. DeSaix, when we wrote it, and when we left the classroom. As a result, we never received any feedback on our project through this mechanism.

This case illustrates a failure to keep track of project *deliverables* and *deadlines* as the project *scope* evolved. Since Ned and I lost track of the how the project changed over the course of the semester, we neglected to create the project description in a form (such as a printout, or an email) that fit with Dr. DeSaix's PIM system. This lack of fit in turn contributed to the paper being lost. This case can be seen as example of the intersection between project management (scope, deadlines, and deliverables) and PIM (information format, storage, and refinding).

Theme 2: Collaboration

Students in BIO 101H collaborated on group research projects, which culminated in group presentations. On these group projects, collaboration was intertwined with project management. On individual projects, students were still responsible for project management tasks, but without the added complexity of sharing and coordinating workloads and information. Collaboration was seen to influence PIM behavior, as information for group projects was gathered, organized, and retrieved in order to support collaborative work.

Students were observed collaborating both in person and online. In-person collaboration included working together using tools such as a laptop or desktop computer, paper notes, articles, and books. Online collaboration typically entailed sending emails among project group members. Other common collaborative tools, such as wikis, file sharing, chat, and screen sharing, were generally not observed in BIO 101H. Only one student was observed to employ a dedicated collaboration tool—Google Documents, a collaborative word processing and spreadsheet tool.

I observed little use of collaborative strategies, such as assigning specific roles/responsibilities/deliverables; preparing and using meeting agendas; engaging in consistent follow-up with team members; and project planning/scheduling).

Representative Cases

Case 2.1: Ambiguous agendas for and conclusions to group meetings.

My first project group focused on the topic of why it has been so difficult to develop effective treatments for HIV. One of the first actions we took was to schedule a meeting by talking in class, and then Nora sent an email confirming the meeting:

```
Hey team,

Quick summary: we're meeting Monday afternoon at
1:00 pm in the union by Alpine to discuss our
project. Prof. De Saix mentioned that it's
completely ok to do what we were originally
planning (why is HIV so hard to treat) even
though it was covered in the article because we
really didn't talk about it in class. So let's
come in with specific information and ideas on
how we can present.

See you all then!

Nora
```

This email suggested that the purpose of the meeting was to "discuss our project." To achieve this purpose, all group members should prepare "specific information and ideas on how we can present." This expected purpose and preparation for the meeting can be compared with how the meeting actually proceeded. I arrived at the scheduled time to find Tain and Ned; the other two group members (Nora and Tim), didn't show up. The three group members in the meeting had a general conversation about ideas for the format of the presentation, including "creative" ideas, like role-playing. However, we did not reach any specific consensus on what format or approach to use for the presentation. In contrast to the expectation, set by Nora's email, that attendees should have "specific information and ideas on how we can present," no one had done any research on the topic, other than my sending out single article from *The New Yorker* about vaccines.

Ultimately, our conversation led to discussion of this research question: Why we can create vaccines for the flu (annual flu shot) by analyzing the shifting strains and developing an appropriate vaccine response, but not for HIV? Ned and Tain agreed to meet at the Health Sciences Library on the following Wednesday at 12:00pm to research this topic and related issues. Since a requirement of the assignment was to find at least two library resources, Tain also said he would do some catalog searches online before Wednesday.

Tain opened a paper planner in which he had penciled in his class times. He noted the scheduled library meeting in this planner. Nate had opened his laptop almost as soon as we started talking, and seemed to be taking notes on it. While it wasn't clear if Ned explicitly made a note of the meeting time or not, I checked in with Tain on Wednesday and learned that Ned did not show up for the meeting at the HSL.

Finally, it appeared that having two people from the group missing from the meeting led to gaps in collaboration and coordination. What was needed to move the project forward, and who was responsible for which components, seemed to be ambiguous. This ambiguity and uncertainty was consistent with other meetings, which ended with an unrealized need for further contact and action. On at least three occasions, I had to ask for help at the end of a meeting with understanding what would happen next, so I could fulfill my role as a student participant. I asked questions such as "So, are you going to going to email us about this?" Without such questions, it seemed no specific plan would have been identified.

Illustrative Cases

Case 2.2: File versioning and names

During a meeting of my second project team (focused on analyzing genomic data), we had to integrate and describe work we had already done. Melissa and Ned needed the latest version of the spreadsheet we had worked on, so they could incorporate the results of our analysis into the PowerPoint slides we were preparing. Lena had created the spreadsheet originally. She named it "Datacrunch.xls," and then a subsequent revision "Datacrunch-2.xls." I had to find this spreadsheet on my PC and email it to Ned and Melissa. They expected me to email it to them, even though we were working together in the same room, and Melissa and Ned were physically sharing one computer. I renamed the file to "Datacrunch-3.xls" to be consistent with Lena's choice, and emailed it to them.

By transferring the spreadsheet from my computer to Melissa's computer, I potentially created further collaboration and refinding problems. It appeared that Melissa chose her own, personal filename for the spreadsheet when saving it to her computer. When she and Ned then made changes to the spreadsheet, and saved those changes on her computer, the spreadsheet became out of sync with the versions that Lena and I had saved on our own computers.

Theme 3: Dynamic, evolving task structures

Tasks in BIO 101H were observed to change and evolve during the semester. In multiple class sessions, Dr. DeSaix added or modified readings, research assignments, and other tasks she expected students to complete. Examples of new tasks included "find a carbon calculator online and use it to calculate a personal carbon footprint," and "sketch the stages of mitosis in a salamander cell." Examples of modified tasks included "read a handout provided in class," or "read only a portion of what is listed as assigned reading on the syllabus."

Tasks were also modified by sending email to the class, or posting announcements on Blackboard. Three aspects of these *ad hoc* tasks were particularly noteworthy. First, tasks were introduced in class at a variety of different times (for example, there seemed to be no convention that new tasks would be introduced at the beginning or end of class). Second, these tasks were observed to have deadlines within a week of being mentioned. Third, these tasks sometimes lacked a physical or electronic artifact that could anchor reminding and task management. In some cases, Dr. DeSaix sent an email to the class or posted an announcement to Blackboard related to the new task. In other cases, she did not. Thus, students could not assume that there would be a cue to remind them of the new (or modified) task. Overall, it appeared that students were expected to keep track of a constantly evolving landscape of tasks.

Another aspect of dynamic, evolving tasks in BIO 101H was that the scope and structure of assignments appeared to be under constant negotiation. For example, during the post-class period one day (as students were gathering their bags and leaving), a student asked about the research paper which was mentioned on Blackboard, but had not been discussed in class. Dr. DeSaix said about this assignment that "it's worrying me" and "I'm rethinking that assignment." She redesigned tasks based on her perception of students' progress and workload. In an interview, Dr. DeSaix noted that she is comfortable maintaining a dynamic, evolving set of tasks for students. Based on her assessment of the progress of this particular group of students, she sought to adjust the final research project to make it "less stressful" than in past classes she has taught. This adjustment also entailed changing the scope of the project, and required students to understand and keep track of this modified project information.

It also seemed challenging for students to work with a constantly evolving landscape of tasks, and integrate these tasks into their PIM systems. Students were observed to have difficulty structuring and storing information about these dynamic tasks in their PIM systems. As a result, it appeared that students completed "static" tasks (those listed on the syllabus that did not evolve) with greater ease and less stress than with dynamic tasks that changed and evolved during the semester.

Representative cases

Case 3.1: Dynamic, evolving group research project

BIO 101H included a final research project assignment, but the syllabus did not list this project. The syllabus was updated twice during the semester, but even the final version did not list the project. Dr. DeSaix mentioned the project in class twice before March 8th, and implied that the project would require a formal research paper. She then added this announcement on Blackboard on March 8th: 'I have posted the descriptions of your Final Research Projects under "Assignments."' The description document included new tasks and deadlines that had not been discussed in class, and were not listed on the syllabus. In addition, the description expanded the scope of what she considered acceptable deliverables: "The format of the project may be a paper, a PowerPoint, a poster, or any other medium which you would like to propose." Overall, then, the final project could be characterized as dynamic and evolving during the semester.

Case 3.2: Tracking and reminding of a spontaneous assignment

At the end of one class session, Dr. DeSaix announced an unexpected homework assignment: to diagram phases from mitosis (cell division) for a salamander cell. This assignment was not listed on the syllabus, and was not to be graded. It was assigned to be completed by the next class session, in five days. Students appeared to be surprised at having a task like this announced at the end of class, and unsure of how or where to record this assignment and its due date. At the next class session, the drawings were used to start class discussion about mitosis and meiosis, although some students had not completed the assignment.

Theme 4: Shared awareness/gaps

Situations were observed in which students and the instructor exhibited differential awareness of class assignments, deadlines, and deliverables. These gaps in student/instructor understanding were observed in class and during student group interactions, and were confirmed in interviews with Dr. DeSaix. These gaps were related to modes and frequency of communication as well as the importance of different assignments. For example, students always appeared to know when exams were scheduled, and were prepared to spend time studying for them. In contrast, gaps were repeatedly observed for less crucial assignments, such as final research project (for example, Ned was observed to have forgotten to complete and turn in the topic statement and written summary for this assignment on the day it was due in class). The awareness issues had objective consequences for students' academic performance, including missed assignments. They also appeared to cause frustration and stress for students.

Gaps in shared awareness were seen to influence students' PIM processes, because when students were not aware of assignment information, they could not capture or manage that information. In particular, it was irrelevant if students had effective task management and reminding systems if they were not aware of tasks and deadlines to enter into those systems. Some students who avoided gaps in awareness employed practices and routines, such as routinely checking the Blackboard "Announcements" section every few days.

Representative cases

Case 4.1: Unexpected assignment announcement

At the beginning of one class session, Dr. DeSaix announced that the "summary and references" for the first group project (to be presented the following Sunday at her home) were due at the next class—in two days. This requirement was apparently noted in the assignment information, posted on Blackboard. It appeared that no one in the class was aware of this requirement--either because they didn't see it, or because they noticed it briefly and then forgot about it (when I spoke with Tain after class, he indicated that he had seen the assignment mentioned, but lost track of it). Class-wide confusion was confirmed by the clarifying questions that students asked after Dr. DeSaix's announcement, such as "What precisely do you need altogether?" and "How long does the summary have to be?"

This case is consistent with several similar situations in which the students and the instructor appeared not to share a clear understanding of what was due and when. For example, Ned and I collaborated on the final research project in the class, which involved interviewing someone in the community who works with biology. However, neither of us realized that we were expected to prepare a written summary of our interview, *in addition to* a presentation we delivered to the class. There seemed to be a gap between our mental model of what was expected for the assignment (prepare a presentation, *or* hand in a summary and the instructor's expectation (prepare a presentation *and* hand in a summary). This gap in awareness and understanding made the shortcoming of our PIM systems—such as Ned's paper planner, and my digital to-do list—obvious since we purged information about handing in a summary before it was even entered into our systems.

Case 4.2: Ambiguous assignment expectations

One of the class assignments was to read the book *Flu*, and prepare some "talking points" based on the reading. On the day of class when we were to discuss the book, confusion about this assignment appeared widespread. Discussion during class revealed that Dr. DeSaix had posted a document to Blackboard, explaining the scope and requirements of the "talking points" assignment. However, this document was not listed in the "Announcements" section on Blackboard, nor was there email notification when it posted. In addition, the document was placed in the "Documents" section of Blackboard (as opposed to the "Assignments" section).

Some (but certainly not all) students had seen this document, and then had either emailed her a response, or turned in a hard copy. In an interview, Dr. DeSaix discussed how she was surprised by the confusion that many students exhibited during the class with the *Flu* book and its associated "talking points" assignment. Two students didn't even turn in anything in or after class—she reported that "I chased them down" later to get them to do so.

Theme 5: Affect and Narrative

In this study, narratives and affective responses were repeatedly observed to influence how students captured, processed, organized, remembered, and accessed personal educational information. Affect and narrative are considered together because both elicited emotional reactions, as students and the instructor shared emotionally compelling anecdotes and experiences in class. These stories were observed to heighten students' attention and interest, and focus their perceptions of importance. Although it was not the purpose of this study to assess students' memory for class content, it appeared that students regularly referred to these stories (and implicitly, their emotional resonance) when discussing biological concepts. This focus on affect and narrative also influenced students' making order and refinding behavior, by encouraging them to highlight these stories in their class notes, and to start searches for information in their notes based on their memory of a story.

Illustrative cases

Case 5.1: Humor related to biological concepts

Dr. DeSaix included a variety of humorous stories and phrases in her presentations of biological topics. When discussing meiosis, she said “Don't let your gonads get you in trouble,” which caused the entire class to laugh. Similarly, when introducing gene pools and speciation, she gave examples, including amusing images of mating a Chihuahua and a Great Dane, and the copulating positions of frogs, which induced widespread laughter. These humorous examples and images recurred in later discussions and studying sessions with students, showing evidence of their memorability.

Case 5.2: Sadness related to biological concepts

Dr. DeSaix also told stories with elements of sadness, difficulty, or struggle. When discussing genetic diseases, she explained a particular disease (called PKU), which is caused by genes that code for a defective enzyme, so that affected people can't break down phenylalanine. She told the story of a girl with PKU in a poor rural family, who had trouble managing her complex care regimen—she needed a very precise diet and zero exposure to cigarette smoke, among other requirements. The girl was at risk of dying because her PKU kept getting worse in her environment. This led to the girl being taken to a foster family who also had PKU-positive kids. They helped the girl recuperate, and eventually she was able to start spending time with her biological family again. This story motivated and structured students' memories (and thereby their PIM systems), as it was easily recalled when reading about or studying genetic diseases. This story represents both affective (intense sadness) and narrative (a clear, memorable story) influence? impact on students' memories and PIM systems.

Theme 6: Learning PIM

The field research enabled several observations of students learning PIM in the context of their educational activities. That is, students were seen to improve or expand their PIM skills during the semester. In many cases, students experienced frustrations or problems with an existing practice, which they then attempted to improve or work around. Learning behaviors observed were related to all four core PIM tasks: refinding, reminding and task management, making order, and reflection and metacognition.

Representative cases

Case 6.1: Learning email client productivity

During some of our project group meetings, Melissa expressed her frustration with the capabilities and user interface of the UNC Webmail client. She said she found it slow, difficult to browse through, and that she had a hard time managing attachments. She also said she did not have experience with other applications for accessing her UNC email, including popular desktop clients such as Mozilla Thunderbird and Mulberry. As time passed and she experienced greater frustration with Webmail, she appeared to become more cognizant of the benefits a more powerful email client could provide, and more comfortable with the idea of trying a different email application.

Illustrative cases

Case 6.2: Learning collaborative tools

Lena appeared to be one of the most technically experienced and knowledgeable students in the class. She was enrolled in a programming class, and was observed to analyze and solve complex technical problems on her laptop. Lena was the only student in the class who was observed to experiment with online collaborative tools. During the semester, she was seen to try using Google Docs and Spreadsheets to support some class activities, including sharing a spreadsheet of data analysis with her project group.

Case 6.3: Learning desktop PIM tools

Andy was observed to experiment with desktop PIM tools. He appeared to learn Microsoft OneNote 2007 through a process of trial and error. During one class, he used OneNote to type in a sequence of nucleotide bases from the West Nile Virus as I read them aloud to him from the casebook. At the end of that class, he asked to share my (paper) notes because he inadvertently overwrote or deleted his notes while working in OneNote. He said he needed to "play around" with OneNote more to figure it out, and that he planned to do so in "a class that doesn't matter so much [as biology]… like my philosophy class."

Theme 7: Social Information Management

Students in BIO 101H appeared to use social relationships, structures, and practices to guide PIM activities such as organizing, managing, reminding, and refinding personal educational information. Students were observed to rely on a project group's collective memory and sense of priority for assignments, rather than maintaining detailed individual records. Students regularly engaged in "check-in conversations," during which they accessed other students' perspectives about assignments, deadlines, and class expectations. Students were also observed to use social cues to guide refinding activities, such as accessing project-related information in their PIM systems based on the name of another student, rather than the name or topic of the project. These behaviors indicated that students were relying on their understanding and memory of social roles (such as "friend" or "group leader"), rather than information types.

Representative cases

Case 7.1: Seeking social information through assessment questions

Students were seen to engage in a form of reflection outside of class that centered on "assessment" questions. Students were observed to ask each other for *assessments* of classes and assignments, using questions such as "How do you like the class so far?" and "What did you think of the book?" These questions created the opportunity to begin a reflective conversation that could address topics such as the relevance and usefulness of an assignment or reading to a particular class topic, or a student's own interests. In addition, these questions create opportunities to discuss the specifics of assignments that might have been unclear to one of the students.

Case 7.2: Seeking social information through direct request

As discussed in Theme 4, "Shared awareness/gaps," the class exhibited confusion over the "talking points" assignment for the assigned book, *Flu*. On the day the book was to be discussed in class, I had a conversation with Tain in the hallway. He asked, "what was the assignment for the Flu book?" Tain was unsure what was meant by "talking points," and he seemed hesitant to ask Dr. DeSaix for clarification. Andy had sent an email to the class the night before (using Blackboard) with a similar question about this assignment:

```
   Hey, everyone...

   Does anyone remember what we were supposed to be
doing for the flu book? I know we don't have to do a
paper anymore, but what *is* the assignment? Thanks
in advance!

   P.S. I know there are other people out there who
don't know... if you don't let me know anyway and
if/when I find out I'll let you know too.

   See you tomorrow!
```

When confused about ambiguous assignment expectations, then, students appeared to seek better information and different perspectives through their social relationships with other students in the class.

Theme 8: Priority and Relevance

Priority and relevance were observed to influence students' PIM decisions, such as choosing what information to capture and store, how to organize and label information, and what criteria to use when refinding information. While priority and relevance are highly subjective, a recurrent observation in the class was the apparent primacy of grades in motivating and guiding students' PIM behavior. Dr. DeSaix repeatedly made explicit references about the priority and relevance of particular class material, typically linking priority to an upcoming assignment or test. She emphasized how she sets the scope of the test through her selection of topics for in-class lecture and discussing, by announcing that "if we talk about it in class, it's fair game."

Students' use of priority and relevance were also observed in study sessions that mixed 'strategic' (what to expect on the exam) and 'topical' (what is important about a specific biology topic) metacognition. Students, apparently seeking to attain the best exam grade possible, sought to build an understanding of what topics would be most prominent on the exam. If they could develop an accurate model of what the exam would cover, they could determine which topics were most important to study. This sense of importance then influenced their PIM behaviors, including what resources they searched for and stored, and how much effort they devoted to organization and annotation.

Students were observed to employ personal strategies to indicate and access priority and relevance within their PIM systems. A range of personal strategies were noted. For example, Tain checked out books from the Health Sciences

Library for his first group research project. He used Post-It notes to indicate sections of the book that were particularly relevant to the project. Other common strategies included using stars or other marginal annotations in the textbook or class notes.

Representative cases

Case 8.1: Instructor-guided priority and relevance

In one class, Dr. DeSaix showed a slide with a "speciation assignment." In this assignment, students were asked to describe the separation of species, describe how the populations became genetically different, and then present the evidence for speciation. Dr. DeSaix did not ask the class to complete this assignment as homework, but instead emphasized how it would make for a good exam question. This emphasis encouraged students to treat this information (about speciation) as highly relevant and important.

A related approach was to emphasize the importance of a particular exam question, especially one that had confused many students. One question that confused many students was about how blindness would develop in a population of cave fish. Dr. DeSaix noted that nearly everyone's answer referred to natural selection and adaptation, ignoring the role of natural (random) variability in the gene pool. In class she encouraged to reflect on this question, and try to understand the nuances of natural variability.

Finally, in other instances Dr. DeSaix would explicitly highlight the priority of a particular statement. When discussing the co-evolution of plants and pollinators, she said “this is one of those things I want you to jot down and think about it.” Such statements could also be seen as an attempt to engage students’ metacognition.

Illustrative cases

Case 8.2: Student-guided priority and relevance

After Dr. DeSaix had introduced the topic of gene expression in class, Mona asked, “why is this topic related to bacteria and viruses?” Bacteria and viruses were the main subject of the textbook chapter the class was studying at the time. Mona’s question suggested she was interested in assessing relevance of gene expression to the primary topic, and perhaps to the scope of the upcoming test. This assessment would in turn influence how detailed and careful her notes on this topic would be, and how extensively she would organize and annotate resources related to gene expression in her PIM systems.

Comparison of PIM Tasks and Themes From Field Study

This study integrated two analytical approaches to students’ PIM behaviors: *task-based analysis*, using the four core PIM tasks (refinding; reminding and task management; making order; reflection and metacognition) and *thematic analysis* (using the eight themes identified by inductive analysis of the field data).

The four core PIM tasks were identified through review and synthesis of the PIM research literature (See Chapter 2, "Conceptual framework"). The eight themes were identified through bottom-up analysis of the ethnographic field data, using a grounded theory approach (See Section 4.1.1, "Data analysis").

Table 12 (following page) summarizes the integrated view of both analyses. It provides an overview of the eight themes, compared to the framework of four core PIM tasks. The cells in the table provide examples of observations that link a particular task and theme. Blank cells indicate tasks/theme combinations where clear exemplar cases were not observed. This juxtaposition indicates how the identified themes in students' behaviors and practices are connected to the core PIM tasks, and provide concrete examples of the tasks based on direct observation and experience.

Table 12. Comparison of observed themes in PIM behavior related to core PIM tasks. Each cell in the table represents an example behavior relevant to a particular theme and a particular task.

THEME ⇉	TASKS / PROJECTS				CONTENT / LEARNING		INFO. ACCESS	
TASK ⇊	*Project management*	*Collaboration*	*Dynamic, evolving task structures*	*Shared awareness / gaps*	*Affect and narrative*	*PIM as learnable skill*	*Social Info. Management*	*Priority and relevance*
Refinding	Review Blackboard for assignment information.	Shared review of captured web pages in MLB.	Instructor changes assignment scope in class.			Student learns MLB, and compares to Google Desktop.		Instructor says "you don't need to write this down."
Reminding & task management		Ambiguous meeting plans/next steps.	Make note in paper planner re: due date.	Students missing planned group meetings.		Instructor encourages students to check Blackboard regularly.	Email to class to clarify assignment.	
Making order	Create collection of project files in MLB.				Students take notes in class re: funny or sad story.		Asking others in study session what to review.	Instructor sets scope of test in class discussion.
Reflection & meta-cognition				Instructor surprised when assignments not received.		Reflecting on own PIM strategies and systems?		Study group: "What do you think she'll ask about this?"

4.2 Research Question 2: Technology probe of MyLifeBits' usage and usability

Research Question 2 asked, "How do students use the MyLifeBits system?" MyLifeBits (Kirsh, 2005) is one of the most developed and tested CARPE/PIM systems. MyLifeBits is frequently referred to as the exemplar of the database approach to PIM (Heylighen & Vidal, 2007). MyLifeBits is based on a SQL Server database containing data and metadata for many types of objects, such as personal contacts, documents, Web pages, email, events, photos, music, and video. Each object type is represented by its own table in the database, which allows MyLifeBits to be continually extended to include new data types. Items in the database can be linked together, annotated, and combined into collections.

My goal in addressing this research question was to understand how students used MyLifeBits to undertake core PIM tasks. Six students participated in the study: four participants were able to use MyLifeBits successfully during the study period; two participants had technical problems running MyLifeBits, but remained in the study as a "control group." I was able to discuss with the control group their natural use of PIM software such as e-mail clients and Microsoft OneNote. All six students remained in the study for the duration, and participated in both interviews and a participatory design session. See Chapter 3, "Methods," for further details on how the technology probe was conducted.

The reporting in this section is arranged into three subsections: the first subsection presents data from MyLifeBits usage logs, and compares MyLifeBits usage to other PIM tools; the second subsection reviews MyLifeBits usage in the context of the four core PIM tasks, and identifies specific usage scenarios related to MyLifeBits and students' PIM needs; and the third subsection identifies specific usability and interaction design issues with the current MyLifeBits design. In general, the usage scenarios and interaction design issues were identified from interviews with students. In addition to interviews, direct observation of students' use of MyLifeBits and heuristic analysis of the user interface informed the development of scenarios and issues.

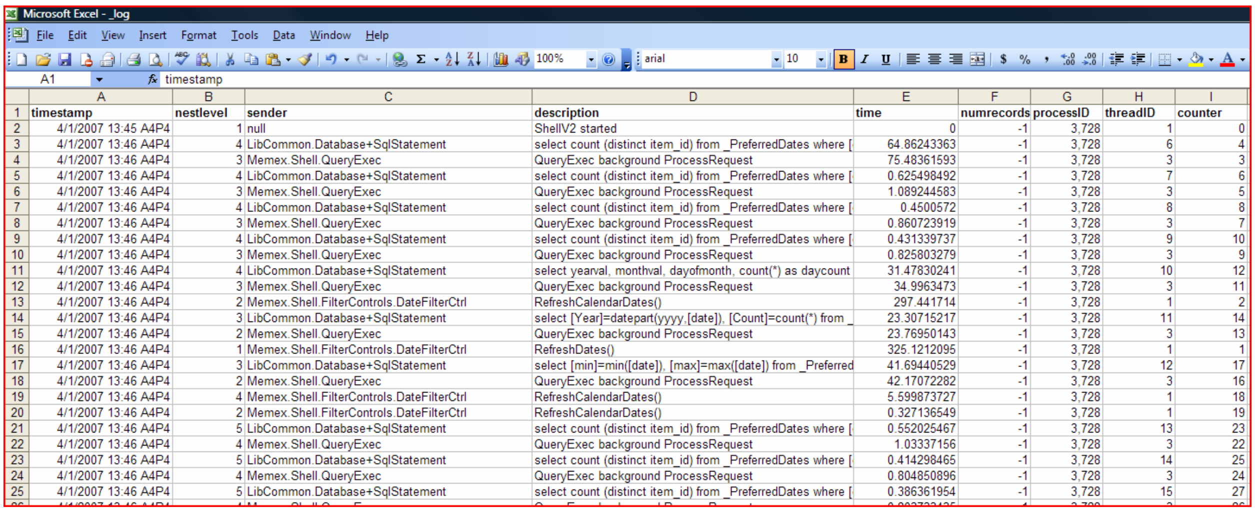
4.2.1 Data analysis

Log data

As configured in this study, MyLifeBits recorded two major types of interaction data that were relevant to this analysis. First, MyLifeBits records the size and content of users' personal archives, including their files, web pages, queries, and collections. Second, installation of MyLifeBits on participants' computers included "GUI Logger," a software component that monitored what Windows applications participants were using, and recorded measures of keyboard and mouse activity in these applications. For example, if a participant opened Microsoft Word, typed in "Hello, World" and then clicked the "Save" icon on the toolbar, MyLifeBits would record a 'keyboard activity' value of 12, and a 'mouse activity' value of around 50, depending on how far the individual moved the mouse. These values would be associated with the application name, "C:\Program Files\Microsoft Office\OFFICE11\WINWORD.EXE," and the time and date on which the activity occurred.

Both types of data were exported from each participant's SQL Server database (using EMS SQL Manager for SQL Server 2.6) into Microsoft Excel files for analysis. Figure 18 shows an example of the Excel output.

Figure 18. Example of log data from MyLifeBits.



	A	B	C	D	E	F	G	H	I
1	timestamp	nestlevel	sender	description	time	numrecords	processID	threadID	counter
2	4/1/2007 13:45 A4P4	1	null	ShellV2 started	0	-1	3,728	1	0
3	4/1/2007 13:46 A4P4	4	LibCommon.Database+SqlStatement	select count (distinct item_id) from _PreferredDates where [	64.86243363	-1	3,728	6	4
4	4/1/2007 13:46 A4P4	3	Memex.Shell.QueryExec	QueryExec background ProcessRequest	75.48361593	-1	3,728	3	3
5	4/1/2007 13:46 A4P4	4	LibCommon.Database+SqlStatement	select count (distinct item_id) from _PreferredDates where [	0.625498492	-1	3,728	7	6
6	4/1/2007 13:46 A4P4	3	Memex.Shell.QueryExec	QueryExec background ProcessRequest	1.089244583	-1	3,728	3	5
7	4/1/2007 13:46 A4P4	4	LibCommon.Database+SqlStatement	select count (distinct item_id) from _PreferredDates where [	0.4500572	-1	3,728	8	8
8	4/1/2007 13:46 A4P4	3	Memex.Shell.QueryExec	QueryExec background ProcessRequest	0.860723919	-1	3,728	3	7
9	4/1/2007 13:46 A4P4	4	LibCommon.Database+SqlStatement	select count (distinct item_id) from _PreferredDates where [	0.431339737	-1	3,728	9	10
10	4/1/2007 13:46 A4P4	3	Memex.Shell.QueryExec	QueryExec background ProcessRequest	0.825803279	-1	3,728	3	9
11	4/1/2007 13:46 A4P4	4	LibCommon.Database+SqlStatement	select yearval, monthval, dayofmonth, count(*) as daycount	31.47830241	-1	3,728	10	12
12	4/1/2007 13:46 A4P4	3	Memex.Shell.QueryExec	QueryExec background ProcessRequest	34.9963473	-1	3,728	3	11
13	4/1/2007 13:46 A4P4	2	Memex.Shell.FilterControls.DateFilterCtrl	RefreshCalendarDates()	297.441714	-1	3,728	1	2
14	4/1/2007 13:46 A4P4	3	LibCommon.Database+SqlStatement	select [Year]=datepart(yyyy,[date]), [Count]=count(*) from _	23.30715217	-1	3,728	11	14
15	4/1/2007 13:46 A4P4	2	Memex.Shell.QueryExec	QueryExec background ProcessRequest	23.76950143	-1	3,728	3	13
16	4/1/2007 13:46 A4P4	1	Memex.Shell.FilterControls.DateFilterCtrl	RefreshDates()	325.1212095	-1	3,728	1	1
17	4/1/2007 13:46 A4P4	3	LibCommon.Database+SqlStatement	select [min]=min([date]), [max]=max([date]) from _Preferred	41.69440529	-1	3,728	12	17
18	4/1/2007 13:46 A4P4	2	Memex.Shell.QueryExec	QueryExec background ProcessRequest	42.17072282	-1	3,728	3	16
19	4/1/2007 13:46 A4P4	4	Memex.Shell.FilterControls.DateFilterCtrl	RefreshCalendarDates()	5.599873727	-1	3,728	1	18
20	4/1/2007 13:46 A4P4	2	Memex.Shell.FilterControls.DateFilterCtrl	RefreshCalendarDates()	0.327136549	-1	3,728	1	19
21	4/1/2007 13:46 A4P4	5	LibCommon.Database+SqlStatement	select count (distinct item_id) from _PreferredDates where [	0.552025467	-1	3,728	13	23
22	4/1/2007 13:46 A4P4	4	Memex.Shell.QueryExec	QueryExec background ProcessRequest	1.03337156	-1	3,728	3	22
23	4/1/2007 13:46 A4P4	5	LibCommon.Database+SqlStatement	select count (distinct item_id) from _PreferredDates where [	0.414298465	-1	3,728	14	25
24	4/1/2007 13:46 A4P4	4	Memex.Shell.QueryExec	QueryExec background ProcessRequest	0.804850896	-1	3,728	3	24
25	4/1/2007 13:46 A4P4	5	LibCommon.Database+SqlStatement	select count (distinct item_id) from _PreferredDates where [	0.386361954	-1	3,728	15	27

Measures were selected from the log data were chosen to characterize typical MyLifeBits use, and compare students' use of MyLifeBits to other common PIM applications. These measures were organized into three groups (see Table 13).

Table 13. Log measures used to characterize typical MyLifeBits use.

1. Overall usage measures	a. Amount of user interface activity (keyboard and mouse) in the MyLifeBits shell.
	b. Amount of user interface activity (keyboard and mouse) in the participant's email client.
	c. Amount of user interface activity (keyboard and mouse) in Windows Explorer.
2. Refinding measures	a. Number of queries executed in the MyLifeBits Digital Memories shell.

	b. Number of queries executed in the MyLifeBits Internet Explorer toolbar.
	c. Number of archived web pages accessed through the shell.
3. Making order measures	a. Number of collections created in MyLifeBits.
	b. Number of archived web pages stored in MyLifeBits.

The usage data were calculated using filters in Excel. For example, to determine the amount of user interface activity in MyLifeBits, the usage log was filtered to show only log events for which the window title contained "Digital Memories." The sum of the keyboard and mouse activity for these events was taken as the total amount of user interface activity (keyboard and mouse) in the MyLifeBits shell. To calculate activity in the email client, the window titles were analyzed to determine which email software the participant used primarily (e.g. Thunderbird, Gmail).

Interviews and observations

Semi-structured interviews (see Appendix A for details) were conducted with participants in the technology probe study. In addition, I observed students' MyLifeBits usage during the course of typical class activities. Data from these interviews and observations were analyzed using an inductive coding process similar to the analysis of the overall field data. However, the focus of data analysis for the technology probe study was to identify scenarios of use and specific user experience issues with the MyLifeBits user interface, rather than to explore general PIM issues. This analysis process was therefore guided more closely by analysis practices in user experience research and design (Elliott, 2007; Susi & Ziemke, 2001) than by qualitative research methods such as grounded theory. The scenarios were organized according to the four core PIM tasks. The usability and interaction design issues were organized according to the MyLifeBits feature to which they related.

Participant profiles

Four participants used MyLifeBits for the full duration of the study, approximately six weeks:

- Edward, a freshman with no planned major, liked to customize his PC and used a wide variety of applications, but had little specific technical or programming experience.
- Tain, a sophomore majoring in linguistics, had a strong mathematics background and was comfortable with technical details of his PC.
- Mary, a sophomore majoring in political science, had limited technical background and rarely explored technical issues on her PC.
- Lena, a freshman expecting to major in biology, was very experienced with customizing Windows and was taking a programming class as part of her coursework.

Two participants tried MyLifeBits but used their own PIM applications during the study:

- Andy, a sophomore majoring in biomedical engineering, had the most extensive technical and programming background, and had installed Windows Vista on his PC.
- Susan, a sophomore majoring in English, had little technical background or interest.

These participants were treated as a control group, and provided a divergent perspective during interviews and participatory design that increased the scope of the findings and design insights.

4.2.2 MyLifeBits usage profile

This research focused on the following specific question related to students' use of MyLifeBits: "How much do students use MyLifeBits, and how does this level of use compare to their use of other common PIM tools?" Based on analysis of the MyLifeBits usage logs, measures were developed to facilitate summary of typical MyLifeBits use, and comparison to standard PIM applications. These measures encompass how many queries participants executed in MyLifeBits, how much user interface activity was reported in MyLifeBits and other PIM applications, and how large a MyLifeBits store participants created. This section presents these results. For each measure, data are presented for the student participants' use of MyLifeBits, and—for comparison—the researcher's use MyLifeBits during BIO 101H.

Overall usage results

Table 14 provides raw data on how much participants used the keyboard and mouse in MyLifeBits, in their e-mail client, and in Windows Explorer. These data are provided primarily to show that students' use of MyLifeBits was nontrivial—they spent time working in the application.

Table 14. MLB activity vs. common PIM tool activity.

Participant	MyLifeBits keyboard activity	MyLifeBits mouse activity	Email client mouse activity	Explorer keyboard activity	Explorer mouse activity
Researcher (for comparison)	467	102,592	100,393	253	20,528
Edward	286	30,271	114,263	2,532	169,229
Tain	1,089	49,166	321,470	4,555	213,612
Lena	420	107,285	1,009,239	2,325	410,180
Mary	116	26,845	260,365	484	83,966
Mean (SD) of participants' usage	**478** ***(426)***	**53,392** ***(37,245)***	**426,334** ***(398,208)***	**2,474** ***(1,665)***	**219,247** ***(138,191)***

This analysis can be extended by comparing MyLifeBits keyboard and mouse activity as a percentage of Windows Explorer keyboard and mouse activity, and e-mail client mouse activity (e-mail client keyboard activity was not examined because most of these keystrokes represented writing e-mails, not completing PIM tasks). These data (see Table 15) show that during the study period, participants' use of MyLifeBits was roughly 1/5 (keyboard) to 1/4 (mouse) of their Windows Explorer use, and roughly 1/6 of their e-mail client use. Again, these data illustrate that participants spent considerable time interacting with MyLifeBits as a PIM system.

Table 15. MLB activity vs. common PIM activity (ratios).

Participant	*MLB keyboard / Explorer*	*MLB mouse / Explorer*	*MLB mouse / Email*
Researcher (for comparison)	185%	500%	102%
Edward	11%	18%	26%
Tain	24%	23%	15%
Lena	18%	26%	11%
Mary	24%	32%	10%
Mean (SD) of participants' usage	**19%** ***(6%)***	**25%** ***(6%)***	**16%** ***(8%)***

Refinding measures

Table 16. MLB usage statistics.

Participant	Number of MLB queries (Shell)	Number of MLB queries (IE)	Number of archived web page accesses
Researcher (for comparison)	36	7	614
Edward	8	16	170
Tain	45	140	236
Lena	22	17	10
Mary	0	102	114
Mean (SD) of participants' usage	**19** ***(20)***	**69** ***(62)***	**133** ***(96)***

On average, participants entered 19 queries into MyLifeBits using the Digital Memories shell, and 69 queries using the Internet Explorer toolbar (see Table 16). This table also shows the number of times participants accessed an archived webpage from the MyLifeBits database.

Making order measures

Table 17. Size of MLB store.

Participant	Number of archived web pages in MyLifeBits	Number of collections created in MyLifeBits
Researcher (for comparison)	N/A[4]	4
Edward	299	3
Tain	1001	5
Lena	569	1
Mary	N/A[5]	0
Mean (SD) of participants' usage	623 *(354)*	3

As shown in Table 17, participants had hundreds of archived web pages in their databases, which is not surprising given how pervasive Web use is in current University settings. Participants created only a handful of collections on average, suggesting they mainly experimented with this component of MyLifeBits, rather than using it regularly.

---

[4] MyLifeBits SQL database became corrupted, making it impossible to calculate the size of the MyLifeBits store.

[5] Peformance problems with particpant's laptop computer made computing a reliable measure of database size impossible.

Table 18. Typical queries and annotations.

Typical queries—Shell:	Typical queries—Web:	Typical annotations:
Carbon	Notes	"Animal Reproduciton Journal Search" [sic]
DeSaix	ling 523 squib	"First draft of biol 101h final"
Syllabus	specific heat	
	fetal pig anatomy	
	constitutionality of treaties	
	Carbon cycle	

Table 18 provides examples of representative queries and annotations entered by participants. The query examples provide a sense of the specificity and focus participants' queries. The annotation examples provide a sense of the scope and size of participants' typical annotations. On average, annotations were approximately 34 bytes, or about 7 words.

4.2.3 Key scenarios and support for PIM tasks

This research focused on the following specific questions related to students' use of MyLifeBits:

- □ How did students use MyLifeBits in the context of their educational and PIM activities?
- □ Was MyLifeBits able to support students' core PIM tasks in real-world usage?

The scenarios presented below represent how MyLifeBits supported three core PIM tasks—refinding, making order, and reflection and metacognition. No scenarios are presented for reminding and task management because I did not observe students using MyLifeBits to supporting this core PIM task. All quotations in the subsections below are taken from interviews with students regarding their experiences with MyLifeBits.

Refinding

Interviews with students revealed a number of scenarios in which MyLifeBits was used to support accessing previously retrieved information.

SCENARIO 1: Refinding a project-related website or article to support collaboration.

Students reported that they needed to refind information to support collaboration with their classmates as part of a group project. For example, Edward needed to refind a website related to an interview that his partner, Jason, was conducting for the final research project in BIO 101H. Edward reported that he found it easier to retrieve items in MyLifeBits than to re-create a search for a particular website online. The same was true when conducting research in online literature databases. Edward said he found MyLifeBits "helpful with Academic Search Premier, the database."

His procedure was to search for literature via his Web browser, then refer back to the cached copies of pages in MyLifeBits as needed (instead of saving individual PDF's found during a search session, or printing out articles). He reported that, “whenever [he was] looking for articles to use in class,” he would show items from MyLifeBits to his group partners, Emily and Jacob, saying “here’s the stuff we could use.” So, sharing a single MyLifeBits screen, during a physical meeting, substituted for behaviors such as e-mailing links back and forth, or sharing printed copies of an article.

Based on his experience using MyLifeBits during a group project, Edward suggested the idea of being able to share a collection with project partners—“he could take a collection and send it to someone as an email.”

SCENARIO 2: Refinding ephemeral or difficult-to-search-for websites.

Mary described her difficulty in refinding information for class based on Web searches she had previously conducted. She found it challenging to remember queries that she had entered a few days ago, or even a few hours ago: “I never really know [later] what I type in for my Google search.” In one instance, she was studying fetal pig anatomy for her biology lab. She needed to identify organs within a pig, and so sought to review images of the organs online in order to refresh her memory. She had previously found useful images via a Google Images search, and wanted to refind these pictures. She tried several different queries to try to refind the images, but was unsuccessful. She then realized she could review her browsing history in MyLifeBits, and scan the thumbnails for relevant images (see Figure 19 and Figure 20). She entered a query of "fetal pig" in MyLifeBits, and retrieved 119 items from her Web browsing history. She then scanned through these results to identify the images she wanted. Without this history, she might not have been able to find the exact images she had in mind. "Thank God that I had it!" she said.

Figure 19. Refinding fetal pig images using thumbnail browsing and history search in MyLifeBits (first of two screenshots).

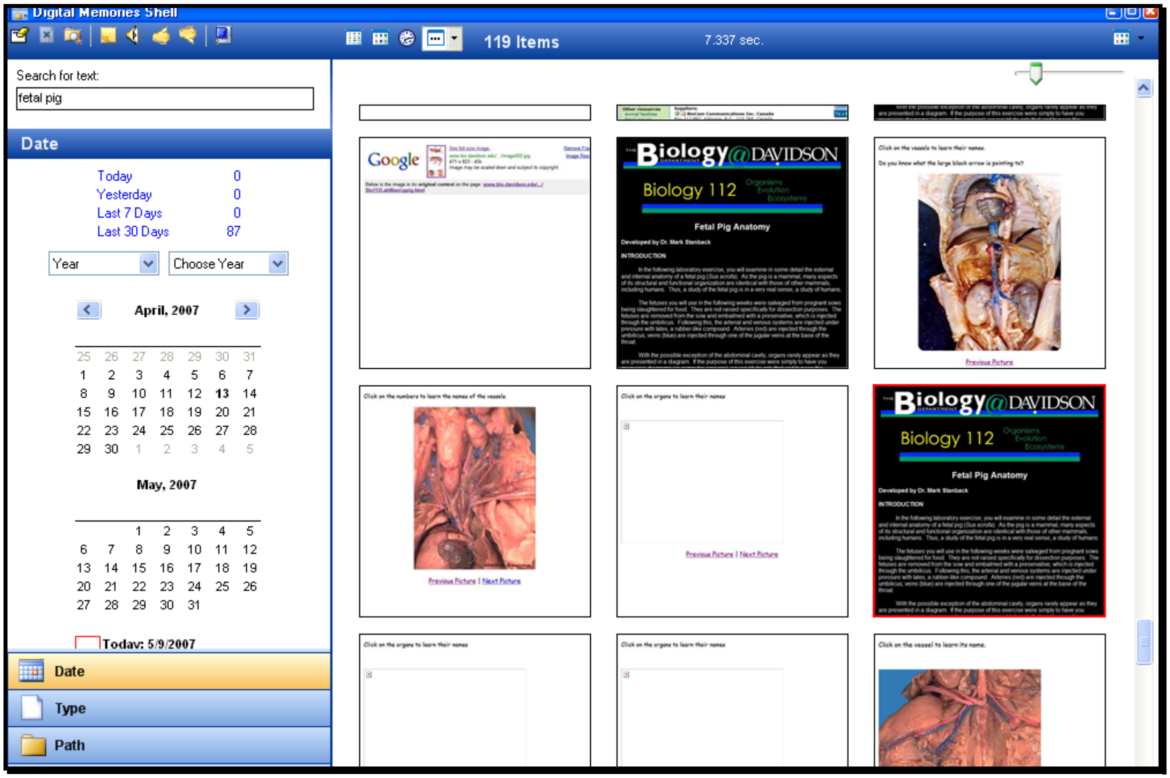
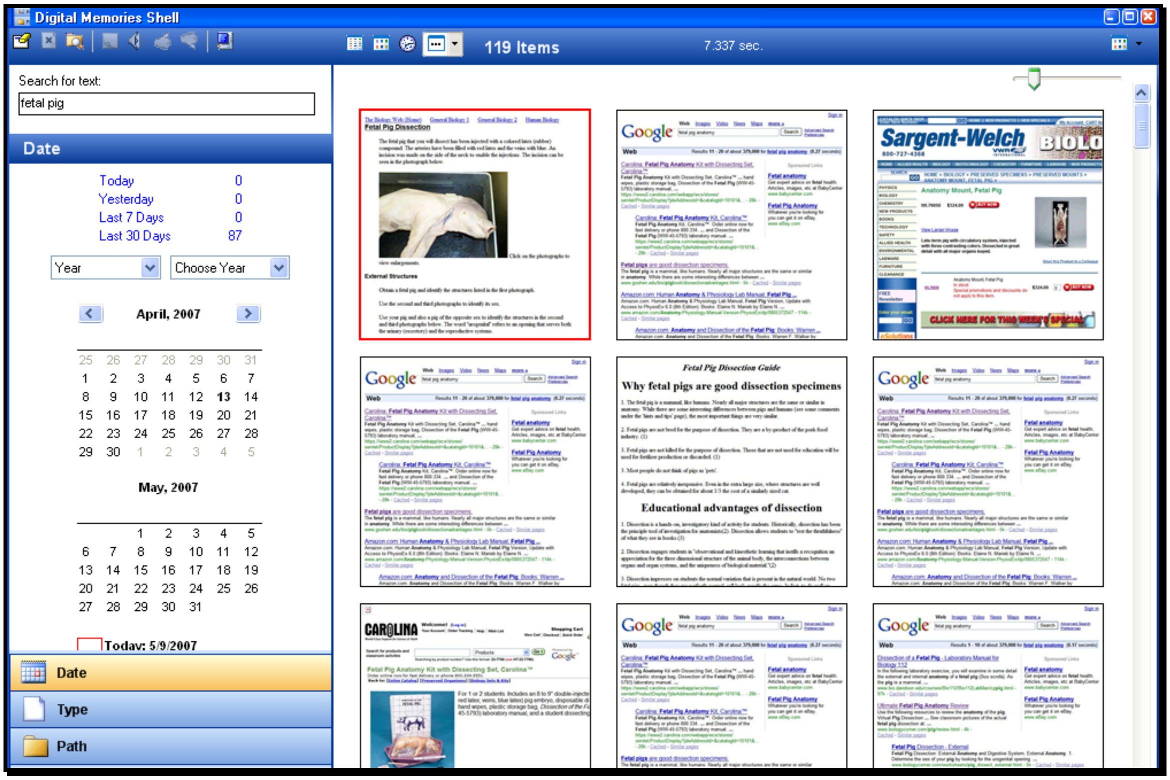


Figure 20. Refinding fetal pig images using thumbnail browsing and history search in MyLifeBits (second of two screenshots)



Mary conducted a related refinding activity for a different class. In this history class, she also needed to refind web pages that she had originally discovered during a search. Because these largely textual pages were less amenable to thumbnail browsing, she said, “I would search for ‘history’ to find ‘history of something.’” With these types of refinding activities, her experience was that “[MyLifeBits] either gave me exactly what I wanted or [the desired information] didn’t come up [at all].”

Edward also had experience trying to re-create earlier searches. He often does quick searches in class: “Whenever I’m just in class—if the teacher says something important or cool, I look it up on the internet real quick, while it’s fresh in your mind—then it’s on your computer.” He found that MyLifeBits simplified returning to sites found during such a search. In contrast, he reported accumulating bookmarks in his Web browser, but found that he rarely uses them to return to Web pages. Like Melissa, Edward found MyLifeBits particularly valuable when he could not re-create his original query. In one instance, he sought to refind the website of a professor who could help with his final research project in BIO 101H:

> "[MyLifeBits was] helpful for finding this professor's website—I found it in class while talking about it—[but it was a] weird way to get to professor's website... I couldn't get back to it through Google—[I was] looking for links that had changed color on the page, but didn't see them."

MyLifeBits helped him to complete this refinding task.

Tain investigated burn research and treatment for his BIO 101H final project. He described trying to refind "one page in particular on the American Burn Association's website—their database for the national burn repository—thinking that [search] would be kind of specific but [MyLifeBits] gave me a really long list." This is an example of a case where MyLifeBits' comprehensive capture capabilities may have limited efficient information retrieval. Tain wanted a high-precision search results, but he received high-recall search results instead.

SCENARIO 3: Visual refinding.

Four participants reported that visual refinding using thumbnails (see Figure 21) was a natural and productive interaction style. Edward noted that having a visual overview was particularly helpful: "I like the thumbnail view, especially for websites it helps a lot." He found the slider bar valuable for setting thumbnails to a useful size. In his experience, "most thumbnails views [in other applications] give way too small a picture—the slider makes the view useful." Tain also stated that thumbnails were "the most useful in most cases—I didn't really use other views for the most part."

Both Lena and Melissa were explicit about the value of thumbnail images of web pages, and being able to browse visually through one's Web history (see Figure 21 and Figure 22). Lena said, "Going back through web pages, being able to see them in this format [thumbnails] is really nice (although if they have similar formatting, sometimes it's hard to tell which is which)." She thinks thumbnails are "more like actually playing with tangible stuff," which is easier and more pleasant than working with queries and textual results. Melissa thought that, "it was most helpful to see them [web pages] the way that I visited them—that represents my chain of thought."

Figure 21. Browsing through thumbnail images of recently visited web pages in MyLifeBits.

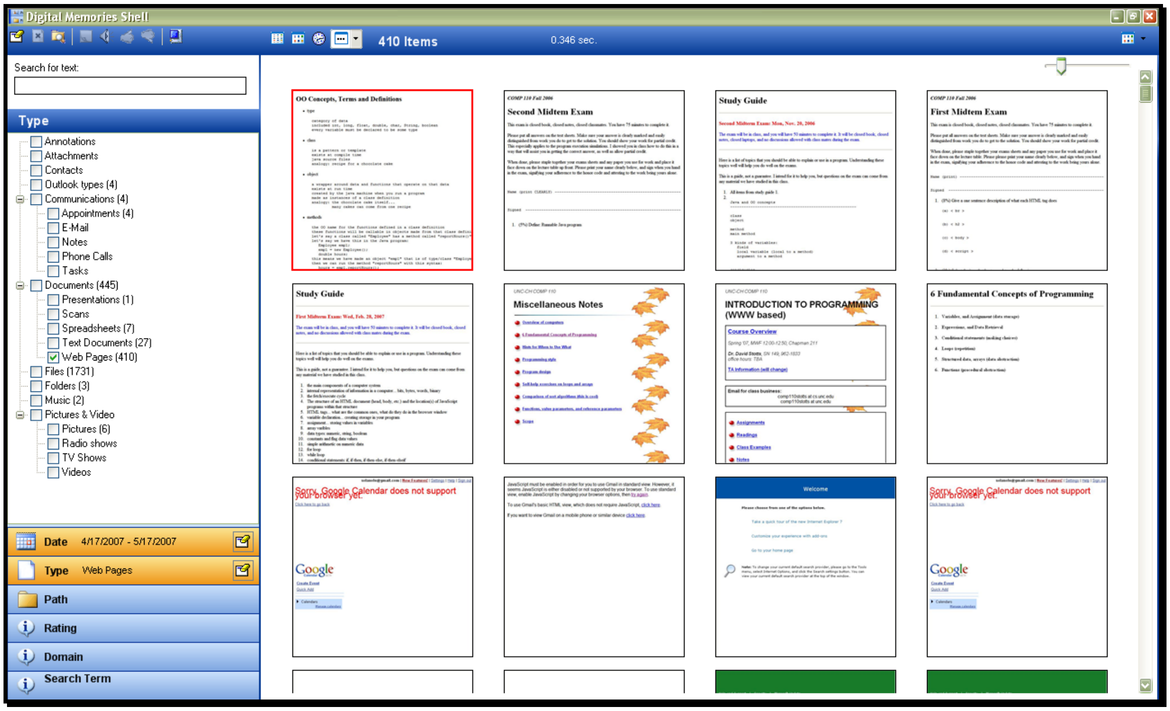
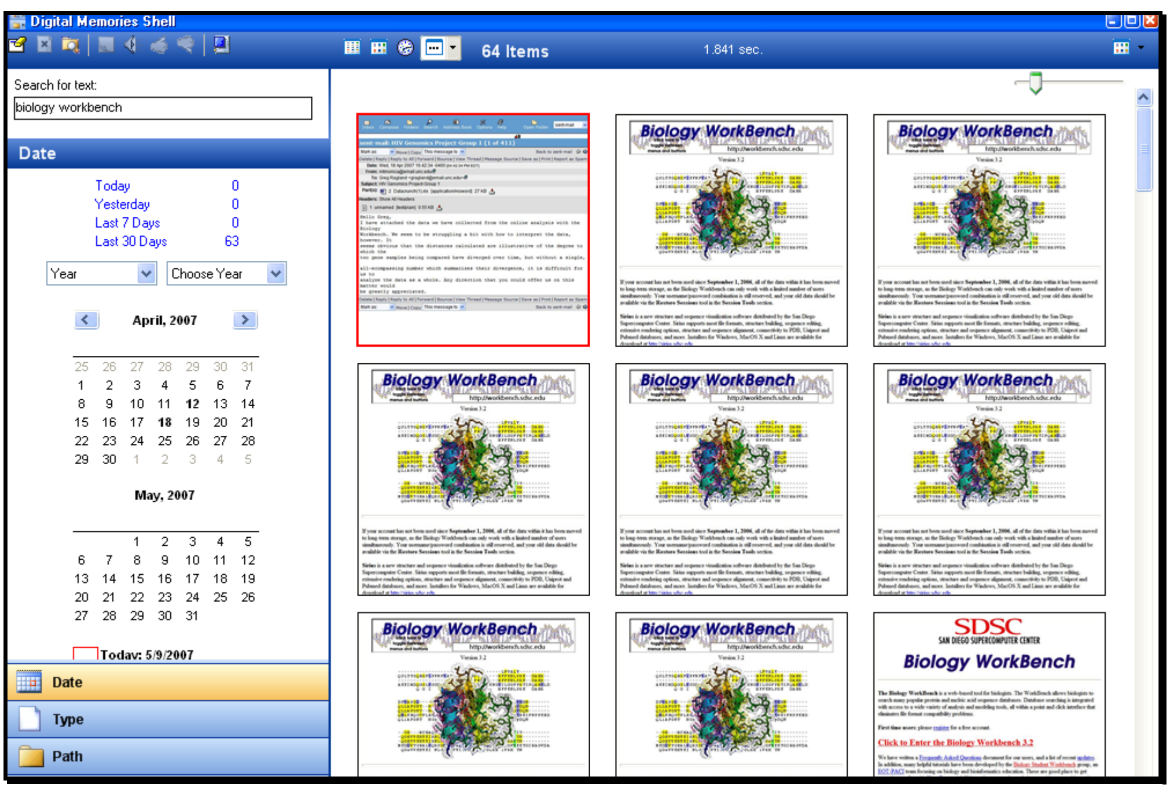


Figure 22. Searching through visited web pages in MyLifeBits, using thumbnails.



SCENARIO 4: Local file refinding.

Three participants reported being less concerned with refinding local files in a folder than with refinding web pages and other online resources. Lena did report that she found it easier to search in MyLifeBits than to navigate through Windows Explorer. She chose to access her biology class notes (contained in individual Microsoft Word documents) by searching for “notes” in MyLifeBits, and then limiting the search results to a particular folder on her system. She pointed out that “I’m a keyboard person,” which influenced her preference to type in a query rather than navigate through a folder structure.

Students also noted that MyLifeBits could potentially be useful in overcoming the limits of conventional file names. Edward pointed out that a thumbnail view might be useful for local files as well as for web pages: “[Thumbnails] could also be helpful for PowerPoint’s, because downloaded files often have weird file names—thumbnails would be easier to recognize.”

Making order

SCENARIO 1: Adding contextual information with annotations.

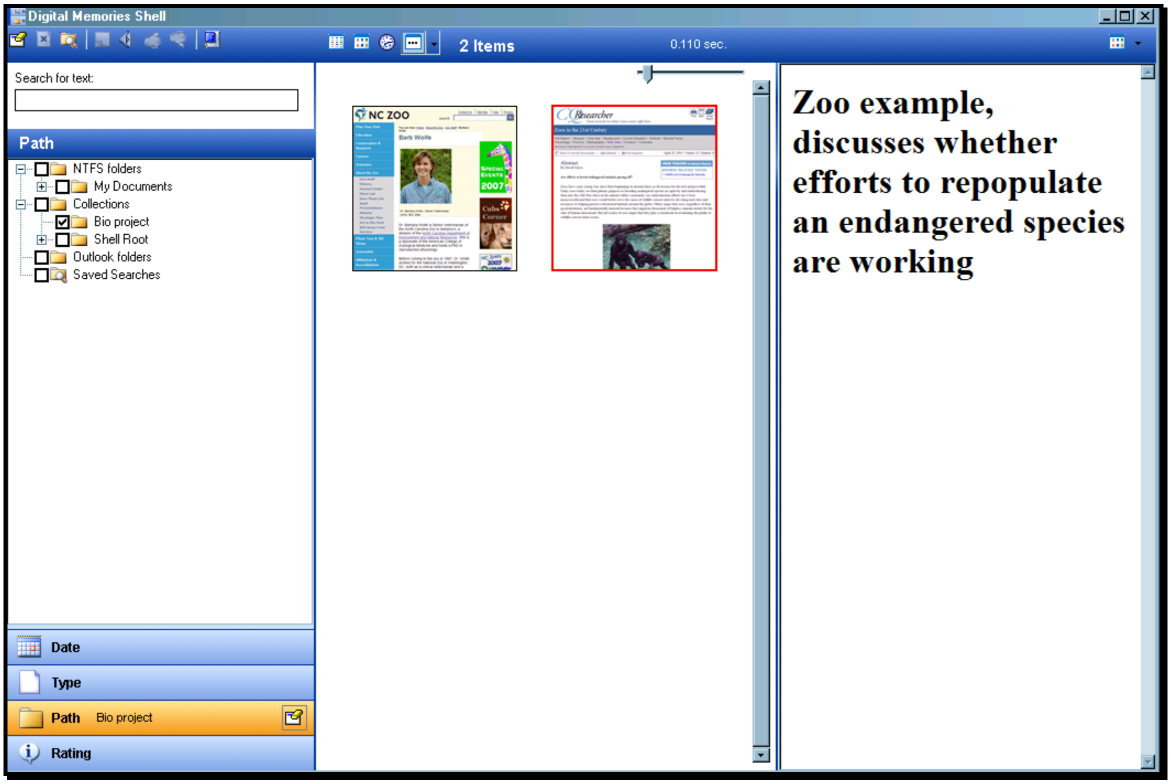
Edward discussed how he “added some text annotations to a couple of the things.” He used the annotations (see Figure 23) to describe the potential use of items (i.e., how they would support his project work). As the figure illustrates, thumbnail images of the captured web pages were shown in the middle pane, and

Edward entered his annotation in the right-most pane. Edward described to primary cases in which he would annotate items in MyLifeBits. First, he would annotate journal articles with a brief summary and description of the topic the article covered. Second, he would annotate websites related to his group project with information about why the website was relevant to the project. For example, his partner Jacob needed to interview a professor for their project. Edward annotated the professor's homepage with the following text: "Jacob's interview person—this is the professor that specializes in elephant reproduction."

Edward also noted that the problem of cryptic file names, particularly with files downloaded from class websites or Blackboard. Annotations can be used to describe files with unclear names. Lena similarly noted that, "a lot of files in folders are from Blackboard—I go with whatever name the file downloaded as," but these default names are often provide little description.

Mary said that, "I liked being able to annotate things that I used more often." When working on her group project, she relied on annotations to direct her to the key resources: "instead of looking for web sites again for the HIV project, I didn't commit that website to memory [because I can rely on the annotation]."

Figure 23. An example of a students' annotation for a webpage in MyLifeBits.

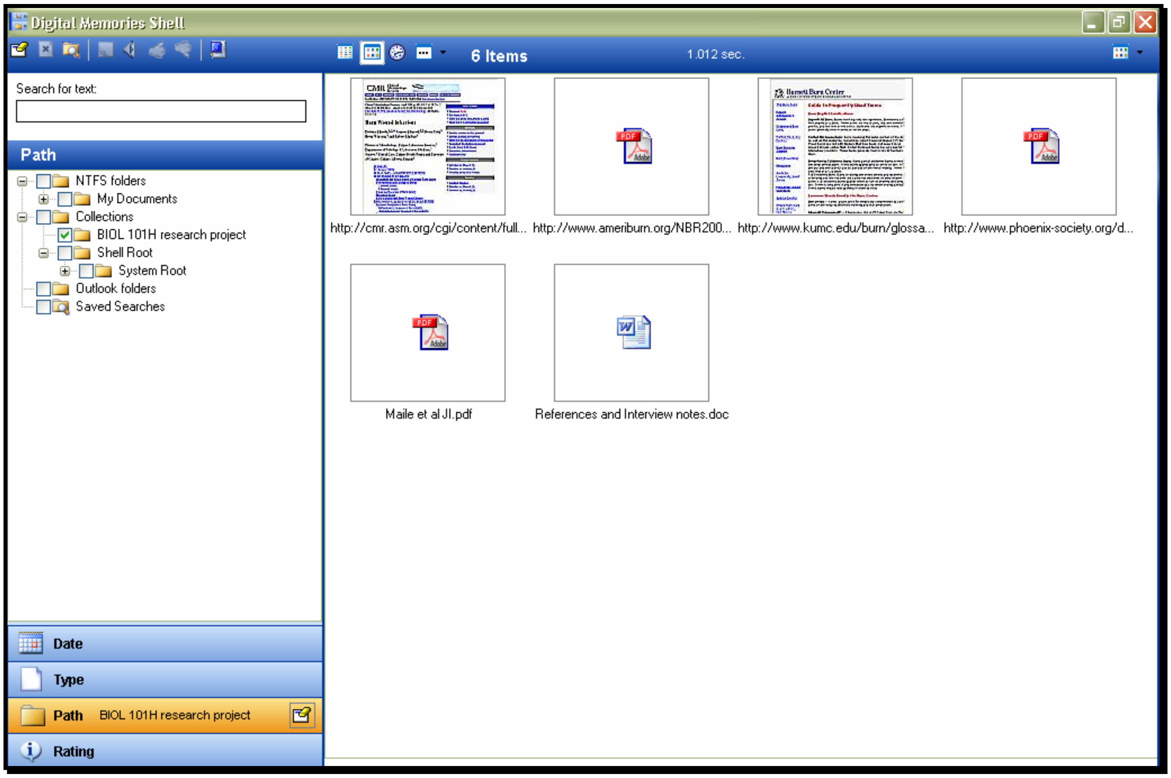


SCENARIO 2: Creating a personal information architecture with collections.

Participants created collections to store class and project information. They reported being intrigued by the flexibility that collections provided. Figure 24 illustrates a collection that a student developed to hold documents and web pages for a research project on burn treatment. As the figure shows, thumbnails of documents (in PDF and Word formats) and web pages, all related to the topic of burn treatment, are in the collection. Participants frequently described collections in terms of "stuff," suggesting how collections enable a generic conception of an information store, as opposed to “PowerPoint” or “journal articles.” Edward said, “I like how you can make collections of stuff” and Tain said for his biology research project, “I just collected all my sources and stuff.” Edward created a collection containing search results for journals, a professor’s website (the professor he interviewed), and one of the full journals that he used as a source. He “mainly made a collection just of the internet stuff… [with local files] you know where you saved it [so a collection wasn't necessary].”

Edward did not consider the capability of organizing Web pages and local files together as particularly useful. He further noted that it “took me a while to get to actual collections and stuff—you have to clear the search parameters.” Based on these observations, it seems that user interface issues may have inhibited use of collections during the study. Overall, however, participants saw value in the possibility of creating a personal task- or usage-centered IA. In fact, they often pursued this goal using other tools in MyLifeBits, such as annotations and filtered searches.

Figure 24. A collection of materials in MyLifeBits for a biology class research project.



Reflection and metacognition

Participants noted how MyLifeBits' functionality enabled them to easily review their browsing history and other activities. Participants reported that, by facilitating review, MyLifeBits helped encourage them to engage in deeper reflection about their learning progress and time management. For example, Tain found MyLifeBits valuable in providing "a record of all the various ways I've tried to find sources, especially if I've tried something and I didn't think it worked out right then… [if later] I could go back there it might [turn out to] be really useful." Participants found that simply reviewing already-visited information could prompt reflection, because the value and meaning of information evolves over time.

Lena similarly described how she would occasionally browse back through web pages she had visited during the past week, to refresh her memory about what she had seen and to look for anything interesting. She found the sort of review useful, but noted that the redundancy in the browsing history could be frustrating.

4.2.4 Usability and interaction design

This subsection focuses on the research question "What usage and usability problems, if any, were observed? How could the interaction design of MyLifeBits be changed to address these problems?" These questions were investigated using three usability analysis techniques. First, the key MyLifeBits user interface features were examined using heuristic evaluation (Elliott, 2007). In the heuristic evaluation, MyLifeBits' implementation was compared against standardized user interface guidelines to identify areas where MyLifeBits' interaction design could be refined to more closely adhere to the guidelines. Second, problems and breakdowns that students experienced when using the MyLifeBits user interface were collected during interviews with and observations of students. Third, my own use of MyLifeBits over an extended period of time enabled me to identify through direct experience a number of specific issues with the current user interface.

Table 19 summarizes the major usability and interaction design issues, and provides an assessment of the overall usefulness of each of the major MyLifeBits features. This assessment is an overall, qualitative estimation of usefulness, based on observation of students' use, interviews with students, and reflection on my own use of MyLifeBits. The following subsections describe specific user experience issues associated with each feature in more detail. Chapter 5, “Discussion” further explores the implications of these usability issues for the design of MyLifeBits and related PIM systems.

Table 19. Summary of MyLifeBits features and associated user experience issues.

MyLifeBits feature	Usefulness	User Experience issues
1. Web page capture and search	High	**Redundancy.**
2. Thumbnail browsing history	High	**Redundancy.** **Window management.**
3. Timeline	Low	**Confusion.**
4. Search filters	Low	**Parameter management/lack of context.**
5. Collections	Medium	**Adding items.**
6. Annotations	Medium	**Cognitive effort.**
7. Ranking	Low	**Effort.** **Mental model.**
8. Privacy	Medium	**Browsing private or secure websites.**

1. Web page capture and search

Participants valued being able to review and search through previously accessed web pages (the most dramatic example being Melissa's exclamation "Thank God that I had it!" when describing her use of browsing through her Web history in MyLifeBits). However, this feature did exhibit a key limitation: redundancy. Redundancy was mentioned as a recurrent problem by all participants. Tain described the problem as follows: "Multiple copies of the same Web page in search results—if it's one [page] I've had to visit a lot." Tain showed an example of a search for information on burns and burn treatment (related to his class research project) that displayed numerous identical URL's in the results list. Without any additional cues to distinguish, group, or filter the search results, participants reported that even simple searches of the web browsing history could prove frustrating.

2. Thumbnail browsing history

The thumbnail browsing view was vulnerable to the same redundancy issue found with Web page capture and search. In interviews, students showed examples of browsing through MyLifeBits in the thumbnail view, but seeing numerous thumbnails that were identical or indistinguishable. Dynamic websites that could not be effectively cached by Internet Explorer were particularly problematic, as they often filled the screen with identical thumbnail images. A second issue with the thumbnail view was that participants often had to scroll and zoom extensively to reach a useful view. Because the capture history is a comprehensive, participants were often required to scan through a large number of thumbnails to find relevant Web pages. At the same time, they found that a fairly close zoom was often needed in order to see sufficient detail in the image. Participants reported being frustrated by these scanning and zooming tasks.

3. Timeline

Participants reported finding the timeline view confusing, and being uncertain as to how to use it effectively. Lena said, "[the timeline view] confused me – I would just stare at it bemusedly for a while." No participants reported using the timeline view during a refinding task.

4. Search filters

While the MyLifeBits users found search filters effective for winnowing lengthy results lists, they also reported that the filters were difficult to use in some ways. Participants wanted to use the filters to probe and explore different views of search results, but found they could quickly to get lost while navigating the results and filters. Lena noted that it "could be easy to lose search parameters after setting them up—I wanted a back button (take me back, I didn't want to leave!)" Melissa identified a subtler problem. She pointed out that the date filters "didn't work for me because I forget what date [I searched for something on]." This experience suggests the need to incorporate additional elements of context into the search filters. Finally, the specific way in which filters were organized and displayed in the user interface may have inhibited participants' interactions with the filters. In particular, only one set filters was available and visible to the user while searching.

5. Collections

Participants generally found it to awkward create new collections and to add items to collections. Edward reported that he would have preferred to have been able to drag and drop files, web pages, and images directly into a collection. In addition, participants found it difficult to share items from collections when not physically viewing the same laptop screen.

6. Annotations

Participants described creating annotations as arduous, and said they did not want to interrupt the flow of other tasks to annotate resources. Lena said, "it seemed a bit too involved of a process… I figured it would just take a lot of time. Most of the things [resources] are ones I revisit several times, and once I've gone into an assignment several times, I know what it is." Melissa noted that,

> I'm much more of a visual person—and I'm in a rush looking for the page I was using—I didn't want to hover and wait for an annotation to come up when using the simple list, so I could say 'oh that's what's on that page.' … I was only using MyLifeBits when trying to search for something—I wouldn't stop to say 'oh, let's add this blurb.'

Participants' comments suggest that the process of creating and using annotations was not fluid or well-integrated with their PIM activities.

7. Ranking

Participants articulated potential challenges with MyLifeBits's manual ranking features. Lena noted that ranking items in MyLifeBits can be "a fairly tedious process," similar to her experience with annotations. Additionally, Melissa pointed out that the ranking can seem "somewhat arbitrary—I need to keep in mind a sort of system." So both the cognitive load of applying rankings in a systematic way, and the interface mechanisms for ranking items, seemed to interfere with participants' use of the ranking feature.

8. Privacy

Three participants expressed concerns about the privacy of their personal information within the MyLifeBits repository. Melissa was particularly concerned that MyLifeBits would capture screenshots of websites she considered private. For example, she often conducted online banking activities. She was concerned that MyLifeBits might compromise access to her account, or display personal information such as an account number or balance in an archived thumbnail or webpage—even though MyLifeBits provides the capability to turn off archiving while browsing the Web. She often manually deleted pages from the MyLifeBits store to address this worry. The lack of clear indicators of privacy, security, or anonymity in MyLifeBits likely contributed to these concerns.

4.3 Research Question 3: Participatory design session

RQ3 asked, “What design requirements and directions could improve a student-focused PIM system to facilitate learning, reflection, and metacognition?” This section discusses findings from a participatory design session conducted with six students from BIO 101H (see Chapter 3, “Methods” for full details of how the session was conducted), four of whom had used MyLifeBits during the semester. The purpose of this research activity was to elicit scenarios, design directions, and interface concepts directly from students. I anticipated that asking students to contribute directly to conceptual design would suggest new design possibilities that I had not previously considered. The following subsections first discuss scenarios and broad design directions that emerged from the session, and then present specific design concepts that students generated.

4.3.1 Data analysis

The participatory design session generated both raw field notes (observations; students’ comments) and student-created design concepts. See Chapter 3, “Methods,” for more detailed discussion of how the session was conducted, including specific prompts and questions posed to students. These data were analyzed with the goal identifying innovative scenarios and interface ideas that could extend PIM system design in new directions. Scenarios that students generated during the session were identified and were found to align with the four core PIM tasks. The scenarios are therefore reported, below, within this framework. Finally, interactions that could be supported by the design concepts that students sketched were then identified and summarized. Each of the design concepts created by student teams in the design session is shown and described below. Design concepts informed by students' ideas are presented in Chapter 5, "Discussion."

4.3.2 Participants' perspectives on key scenarios and support for PIM tasks

Refinding

Participants in the design session defined a number of scenarios related to the PIM task of refinding, including scenarios involving searching, browsing, and annotation/linking, and potential breakdowns.

Searching

One scenario involved "finding what a professor said about topic X." Another student described this as "find where we were talking about topic x in class." Participants brainstormed ideas such as using speech recognition to generate transcripts of a class session that would enable easy searching. An extension of this idea was to enable simply speaking the topic you want to search for. However, other participants argued that this approach would be awkward in a library or other public setting. A related scenario involved refinding all of one's notes about a particular word or phrase, such as "induced cell death." Participants envisioned that such support would be useful when attempting to study a particular topic in depth.

Browsing

Participants quickly recognized that there might be an array of useful information not captured in their class notes but relevant to the topic they were studying. This led one student to suggest what she called "filter browsing." She described this type of browsing as based on automated categorization of information as you browse it. This browsing would enable students to easily return to particular topics during a later study session. For example, once a student had finished reviewing her notes on "induced cell death," she might turn to all the web pages she had browsed which were related to that topic.

Another student pointed out that this refinding scenario might be involve visual browsing, such as "find a piece of art I like on the web and be able to return to it easily." This visual refinding scenario is analogous to using Google Images to search for a particular type of cell, and using those images when preparing for a biology lab report or exam. The cell image scenario was reported by multiple participants in both the pilot studies and the main study.

Annotation/linking

An alternative to supporting query-based access emerged during the design session, as participants noted their desire to augment notetaking. For example, one participant imagined being able to "describe what happens as a professor writes and talks in class." This student wanted to be able to annotate the audio recording of class with quick notes—an idea is analogous to recording software such as Morae (which is intended to support usability testing), Microsoft OneNote, or audio annotations in MyLifeBits.

Refinding breakdowns

In addition, participants suggested some cases in which refinding might break down. For example, one student was concerned about a web capture system logging information about or images of her online banking activities. Another case involved a direct PIM breakdown. In this hypothetical scenario, a student would come across an interesting webpage, but would be unable to fit into her existing classification structure. While this is most directly a problem of making order, it could potentially also inhibit future refinding tasks.

Task Management and Reminding

Participants in the design session defined a number of scenarios related to the PIM tasks of task management and reminding, including scenarios involving linking, alerts, environment/application control, and collaborative task management.

Linking

Participants recognized that while communications and project information are often closely connected, software applications and websites often separate them They described being able to open messages (such as e-mail, instant messaging, and even Facebook messages) and relate them to other messages and documents. Participants also noted the importance of prioritization, recognizing that only a few messages may be critical to project work and deadlines. Participants suggested a scenario that encapsulates these ideas. Suppose a student wants to review the most recent message from his project group, to determine if he needs to complete anything before class tomorrow. He should be able to easily access this message, and links from it to earlier messages, the original assignment from his instructor, and Web pages he has accessed that relate to this project.

Alerts

Discussion of relationships and prioritization sparked further consideration of the idea of reminding and assignments/due dates. Participants suggested a system that could interrupt or notify users of upcoming deadlines, perhaps with increasing intrusiveness or "sense of priority" as a deadline draws closer. In this system, the user would be able define the importance of projects and assignments, as well as how much time needed to complete them. For example, a 10-page paper requiring some research would be defined differently than a brief due-in-class-tomorrow piece. Participants also envisioned that reminders could be linked to the amount of work accomplished. So, as a student wrote more of a paper, reminders related to the paper could lessen in frequency and intrusiveness.

Environment/application control

Alerting capability could also be linked to activity monitoring. Suppose, for example, someone has an impending deadline, and is browsing Facebook frequently—one student described this as a behavioral cue that could mean "maybe it's time to refocus." If a system could detect such cues, it could help participants focus on pressing work by presenting reminders or indicators of progress.

Collaborative task management

Participants emphasized that their work is increasingly collaborative. Fewer and fewer assignments focus on solitary reading, research, and writing. Participants pointed out that they often need to be aware of assignments, meetings, and information that are arranged or provided by others. For example, a classmate in a student's project group may do extensive online research on her own time. The student needs to be aware of what she has been working on, so he doesn't duplicate or ignore her work. Furthermore, an instructor may expand or refine the group project assignment over the course of the class. The student needs to be notified of these changes and keep track of how they affect his work. So in some cases it can be useful simply to know what other students are working on and how they're doing in class.

Building on these ideas about collaborative work, participants drew analogies to shared notes and desktops. Participants pointed out that physical sticky notes are still in common use. Sticky notes enable students to write anywhere and use different colors, so that they can create visually interesting and appealing displays of notes. Participants suggested that PIM systems should emulate these capabilities (an approach partially implemented by commercial "stick note" software, such as NoteZilla and Sticker). Most directly, one could “put a sticky note on someone else's [PC or online] desktop.” This would be an alternative to sending a message that makes use of the sticky note’s visual form.

Some of the more technical participants were also familiar with screen sharing technologies. Two participants mentioned trying to use screen sharing software, such as NetMeeting, to work with classmates. For example, one student recounted how she wanted to help a classmate with a graphing problem after a lab session, but without being able to visually illustrate the graph, she found it was very difficult to provide assistance. However, both participants encountered technical difficulties when trying to share screens. Other participants noted that it would be useful to be able to develop a class presentation together, and to talk to classmates while sharing the screen with them. These approaches to sharing information and collaborating directly may have appealed to students who had experienced the difficulty of managing PIM systems that included components of many collaborative projects.

Reflection

The discussion made evident that reflection is part of student learning. In particular, participants discussed how they would review or reflect upon a test. One student pointed out that “it's very individual how you would review a quiz or test.” Because of this inherent individuality, it may be difficult to design tools that broadly support reviewing activities. Instead, participants focused on supporting scenarios in which an individual needs to remind himself to take action based on a reflective analysis. For example, a student who receives a disappointing grade on a test could set reminders for himself to review particular portions of the textbook before the final exam.

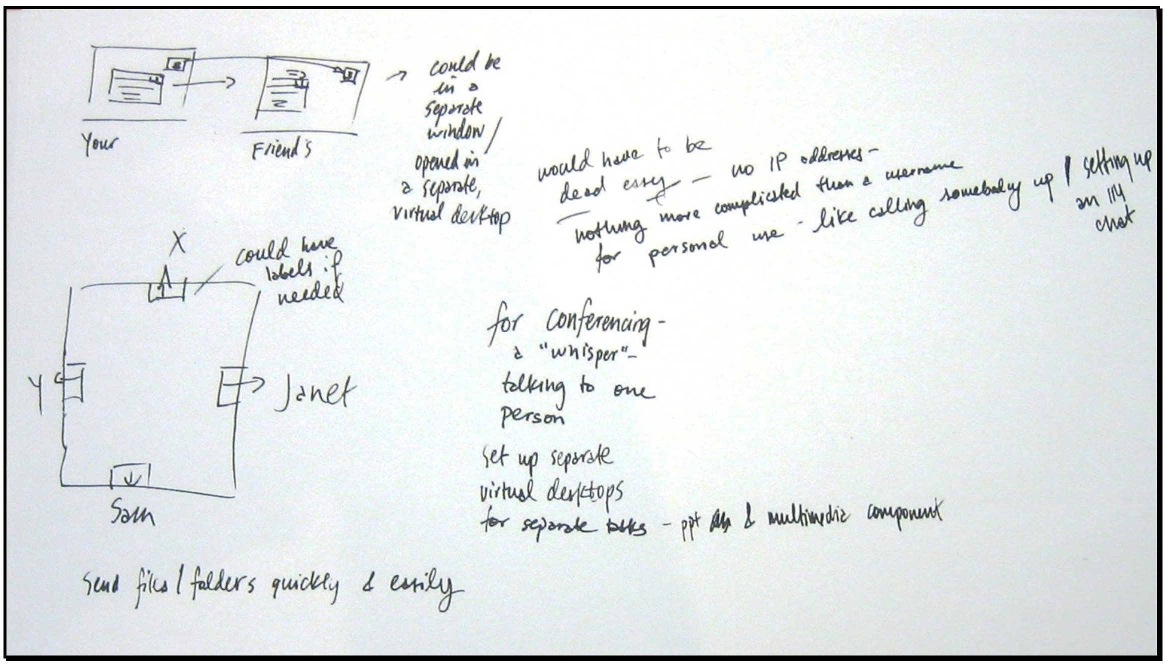
4.3.3 Participants' design concepts

In the design portion of the participatory design session, participants worked in pairs, brainstorming and creating mockup interfaces that could support the scenarios they envisioned. This subsection reviews the interface concepts that the participant teams created.

Participants' Design Concept #1

One pair of participants envisioned a collaboration tool focused on making it easy to share files and images while communicating with another student. They posited a design that would be "dead easy" to use. By "dead easy," they meant that the tool would require no complicated technical setup, such as finding an IP address. They visualized a tool that would be as easy to use as calling somebody up on the phone or setting up an IM chat. Furthermore, this pair specified that the tool should be highly visual. For example, a student would be able to simply drag and drop files or images to share them with another student. In addition to supporting simple person-to-person communication, this tool would also enable a small group to meet and share files quickly. To support private communication while in a group meeting, one would be able to "whisper" to another person. Figure 25 shows students' sketch of this approach, which emphasizes a visual representation of the people in a meeting (the "table" in the left-hand side of the sketch). This representation would be combined with buttons or other interface elements for sending files and folders, and for creating virtual desktops related to specific tasks.

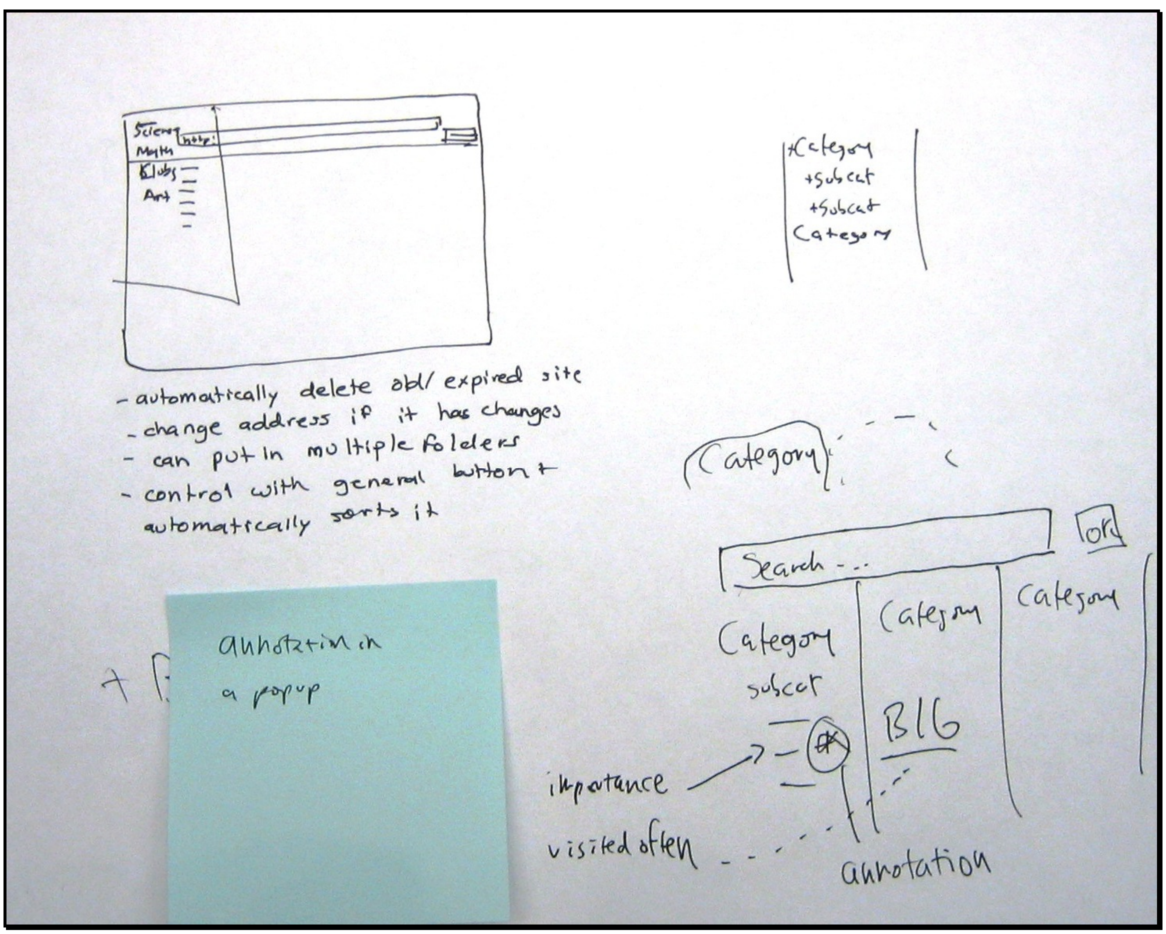
Figure 25. Participants' Design Concept #1: a collaboration tool.



Participants' Design Concept #2

A second design concept focused on improving students' storage and retrieval of Web resources by making bookmarking more powerful and useful. The participant designers of this concept specified that this enhanced bookmarking system would deal intelligently with ever-changing Web resources, by automatically deleting obsolete or expired sites, and updating addresses of sites that move or change. As shown in Figure 26, the system would allow great flexibility in categorizing and retrieving saved resources. The system would enable users to assign pages to multiple categories, add indicators of importance (such as stars, as shown in the bottom-right corner), and add notes. The system would automatically keep track of how often pages were visited, and make often-used pages more prominent in the search results (also shown in the bottom-right corner of the sketch). Student using this system would be able easily winnow a vast collection of bookmarked resources by using incremental (i.e., “find as you type”) search combined with the category structure and indicators of importance and use.

Figure 26. Participants' Design Concept #2: a bookmarking tool.



Participants' Design Concept #3

A third design concept posited a shared file management environment. As show in Figure 28, this concept combined a window for shared editing of documents and images with a list of files, labels, and access to chat. The designers of this concept focused on supporting students' need to work together on documents and presentations for class. This system also incorporated an element of task management, by providing colored labels to indicate the urgency of various assignments (left-hand side of Figure 28). This system would also provide an interface for labeling files, as shown in Figure 27. Overall, this design applied prioritization directly to resources such as a text file or PowerPoint slide deck, rather than using abstract tasks such as "class research project,"

Figure 27. Participants' Design Concept #3: a shared file management environment (sketch 1 of 2).

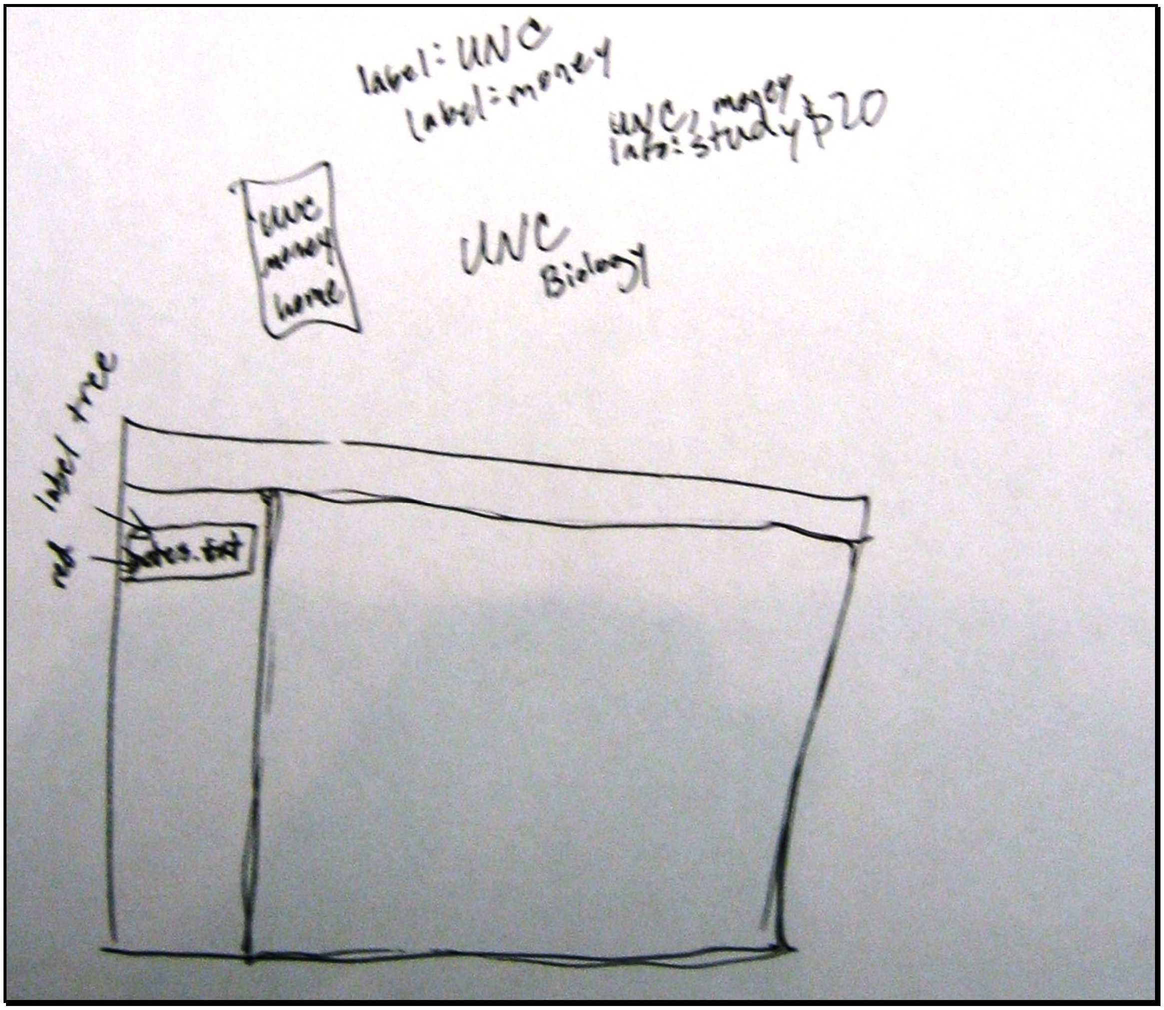
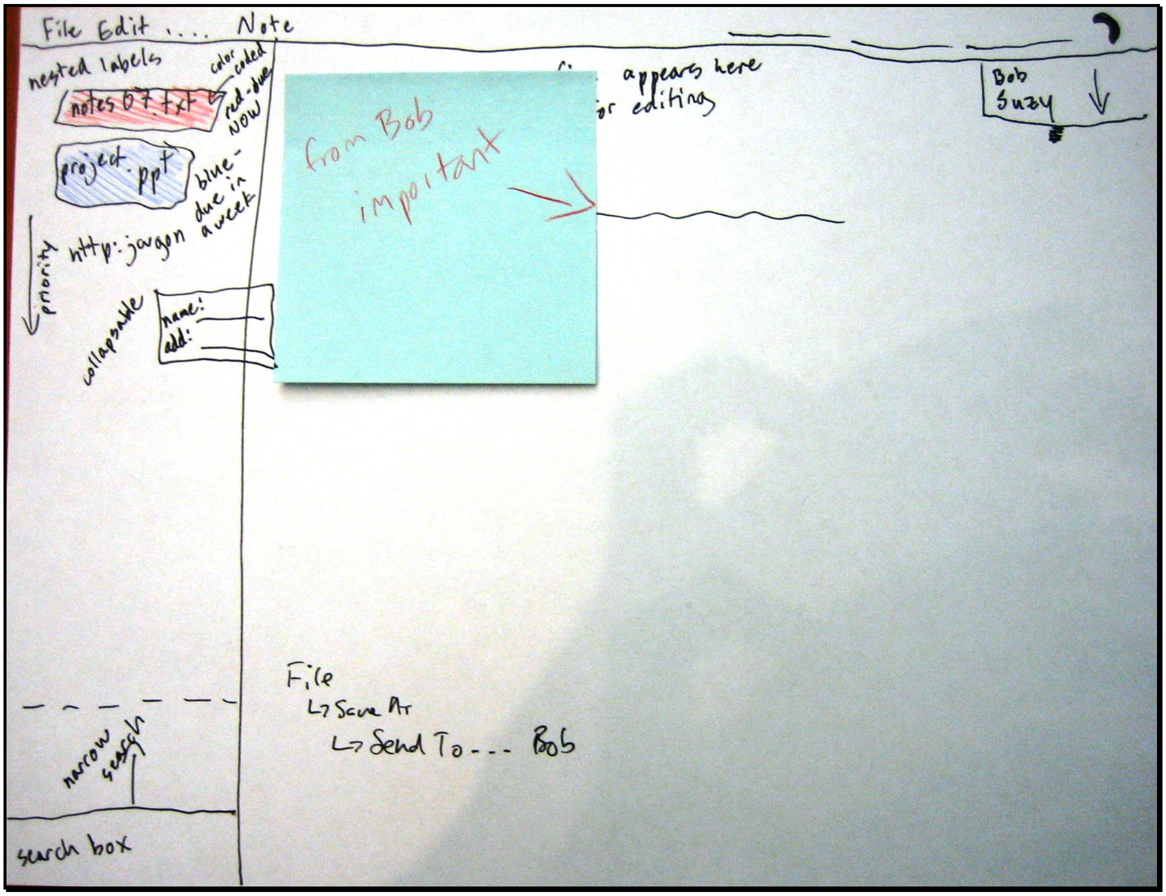


Figure 28. Participants' Design Concept #3: a shared file management environment (sketch 2 of 2)



This concludes Chapter 4, "Results." Chapter 5, "Discussion," continues with a discussion of these results in the broader context of PIM research and design.

Chapter 5: Discussion

5.1 Discussion of Results

5.1.1 Ethnographic field study: PIM behaviors and practices

Research Question 1 asked, "What strategies and practices do undergraduate students use when they manage and retrieve their personal educational information?"

Interpretive analysis of the ethnographic field data resulted in the identification of eight key themes that characterize students' PIM behaviors and practices. These themes both extend and qualify the understanding of PIM tasks and strategies developed in previous research (see Chapter 2, "Conceptual Framework") were considered. In particular, research on people's PIM practices has shown that individuals want to understand and use their information within a personal collection (i.e., an information/task space) that makes sense to them, while minimizing the cognitive and metacognitive costs of filing, retrieving, and using information (Barreau & Nardi, 1995; Boardman, 2004; Ravasio et al., 2004). The present research extends this perspective by considering issues such as the influence of social practices and collaboration on PIM behavior.

The following subsections address the prevalence and implications of these themes, and place them in the context of previous PIM research.

Project management

The results confirm that students are increasingly expected to be project managers, due to the length and complexity of class assignments, the requirements for collaborative work, and the need to identify and integrate many information sources. This research made evident the prevalence and importance of project management offers an opportunity to rethink the scope of PIM, especially for students. It seems that the challenge of PIM is not necessarily that refinding and task management are difficult, but that these PIM tasks are embedded in increasingly complex project work. This finding is consistent with broader changes in the nature of work, as described by Clay Spinuzzi (2006):

> Similarly, when everyone is potentially interconnected, border-crossing is constant and collaboration across functional groups becomes more pervasive. Consequently, workers must take on more of the work that used to be done by managers: planning projects, developing strategic and tactical understandings of their projects, becoming aware of the other projects in which their collaborators are embroiled. They need to become aware of and manage the "working spheres" (Gonzalez & Mark 2004) in which they operate, the overlapping work activities that largely share the same tools but different rules, communities, and divisions of labor.

Students therefore need tools and structures to help them plan projects, monitor project progress, and share diverse types of information easily. The tools I observed students using fell far short of this ideal. Courseware such as Blackboard provides only simple support for refinding and communication (and is often awkward even for these tasks).

MyLifeBits' collections feature offers a more promising model, but in practice provided only limited support for collaboration and project management. For example, Edward reported using MyLifeBits to collaborate by physically showing the collection he had built to his project group colleagues during a meeting. But using this collection to collaborate by sharing resources or project status online would have been essentially impossible for him, forcing him to fall back to less-capable tools such as email.

Collaboration

Collaboration was clearly shown to be a way of life among participants, and was seen to be a major influence on their PIM behavior. Students in this study generally did not explicitly capture or index important information—instead they relied on their collaborators to provide information, remind them of tasks, and so forth. Tang et al (2007) made similar observations in their study of knowledge workers in a large organization: "Computers provide few explicit mechanisms for indicating an expectation of owed work in everyday collaboration. Instead, people tend to socially and contextually negotiate a sense of owing work" (p. 1267). At the same time, integration between students' *communication tools* (emails, IM, Facebook, in-person meetings, class discussions, etc.), *PIM tools* (planners, file systems, etc.), *content creation tools* (Word, Excel, PowerPoint, etc.) and *learning tools* (including specialized biology applications, such as the HIV genomics database) can be haphazard.

In particular, communication tools are largely online (UNC webmail; commercial webmail, such as Yahoo Mail or Gmail; and Facebook) but PIM tools and content creation tools are on the desktop (Microsoft Office, file system, image editing, etc.). Lacking an integrated groupware system or shared repository, students must cope with handling filenames, attachments, and version control on a case-by-case basis. I did not observe students using Web-based collaboration spaces such as wikis or web-based office suites. A possible explanation is that students continue to use the tools they learned in high school—tools they have become comfortable with and use habitually.

So, on the one hand, students' practices and problems are similar to those of knowledge workers (Bellotti et al., 2003; Ravasio et al., 2004). Knowledge workers also struggle to integrate online and offline tools, and to use email effectively to support collaboration. These challenges have influenced system designs such as the Universal Labeler/Project Planner (Jones, Munat et al., 2005). Therefore, there is potential for cross-pollination between field research and system design for knowledge workers and for students.

On the other hand, it is often assumed that knowledge workers' collaboration, time management, and PIM skills are relatively well-developed—although this assumption is, in many respects, unverified. In this research, a substantial skill gap between experienced professionals and (even excellent) college students was evident. In my fieldwork, students' "soft" collaboration skills often appeared primitive. Students lacked understanding of how to meet effectively, establish goals, outcomes and standards, decompose tasks, and follow up with colleagues. Moreover, students exhibited no understanding of why such practices might be important.

I emphasize this point not because it is surprising given the context (freshmen and sophomores in an introductory class), but because of its implications. To collaborate more effectively, students must improve their PIM and collaboration practices. So simply providing "better" tools may have a limited impact, if practices do not also evolve. For example, giving students access to a full-fledged groupware system with powerful scheduling capabilities would likely do little to improve the effectiveness of their group meetings. Instead, students may need to see and experience what a well-run meeting is like.

This argument is consistent with research on "communities of practice" (Brown & Duguid, 2000). Students ultimately need to become familiar with the perspectives and practices of expert collaborators (such as experienced knowledge workers). They need not just to learn "collaboration skills" but also the many tacit understandings and assumptions which underlie effective collaboration. It seems that as students enter the workplace, they may learn these perspectives and practices through direct experience as professionals model effective behaviors, such as creating agendas for meetings, assigning action items, and conducting debriefings after projects are finished. But while students remain in academia, they lack access to this experiential learning of collaboration, and so providing them with collaboration tools may be of little value.

Dynamic, evolving task structures

In this study, students often coped with assigned tasks that were highly dynamic, constantly evolving, and ambiguous. This finding is consistent with other recent research that has examined students' task management challenges.

In an exploratory study of humanities and social science students, Head (2007) found that ambiguous and dynamic assignment expectations were common:

> Students surveyed reported a lack of information from the assigning professor thwarted them the most, sometimes keeping them from beginning an assignment all together. We heard the same sentiment from participants: Trying to figure out what constituted a professor's expectations for an assignment caused 12 out of 13 of the participants the most frustration.

The data gathered also indicate that dealing with evolving task requirements was particularly challenging when tasks lacked physical (e.g., a paper handout) or electronic (e.g., an e-mail from the instructor) cues to support reminding and task management. Instead, students often relied on their memories, with predictable lapses. The evidence of memory problems suggests that memory-enhancing systems, such as a SenseCam, could be valuable in some cases. At the same time, though, new task requirements were often introduced rapidly and informally during the course of class sessions. So even a high-quality, context-enhanced capture system might have few cues to the exact moments when task requirements changed.

Looking at the problem more broadly, it appears that PIM systems are generally based on static structures, such as task lists and calendars, while the tasks and supporting information that students manage are highly fluid. Moreover, the dynamic, evolving nature of tasks often made it difficult for students to develop a coherent inventory of all of their tasks and associated deadlines. Subjectively, I often experienced a feeling of "incompleteness" and stress during class because I was not sure I had remembered everything I needed to read or do to be prepared. These feelings were echoed in the strong emotional responses of students—evident whenever they were asked to turn in an unexpected assignment. Ned muttered "dammit, I hate this class" when he was made aware of a component of the final research project that he had thought wasn't required for him. Nora broke down in tears when explaining how she had not learned of the initial assignment and deadline for the research project.

A variety of practices could help mitigate these issues. Students could learn "hygiene" practices for their PIM systems, such as making a list of every task or reading discussed in class, and then processing the list immediately after class. Or, the instructor could regularly use the last five minutes of class to have students engage in peer-to-peer review of what's due, what problems they're encountering, and so forth. Systems could support these practices by incorporating workflow structures that would help students review their current work status. For example, a dashboard could show all of the students' classes, outlines or checklists for readings, assignments, studying, and other educational tasks.

However, there appears to be a delicate balance between system support that instructors would consider productive and helpful, and support they would consider intrusive. Dr. DeSaix noted in an interview that she believes it is important not to give students too much guidance. For example, she said "we forbid TA's in the lab from sending emails to remind students when things are due." This comment indicated that she treats explicit constraints on PIM support to be valuable because they can encourage self-sufficiency and development of students' PIM skills. At the same time, this perspective relies on an implicit assumption that leaving students 'on their own' will force them to develop and apply effective task management and reminding strategies. Given the breakdowns in coordination, awareness, and reminding that I observed, this assumption is open to question.

Shared awareness / gaps

In order to make progress toward educational objectives, students and instructors must have a common understanding of class structure, assignments, readings, and progress. In practice, I found that developing a shared awareness of what others (peers, instructor, students) know, understand, and feel was surprisingly difficult. Gaps occurred regularly, leading to stress, low-quality work, and reduced learning. These gaps were apparent in both instructor-student communication, and among students working in groups. This problem relates to PIM practices and system design because collaboration played such a central part in students' activities and had such a strong influence on their PIM behaviors.

Some gaps can be attributed directly to system design. The 'invisible' character of updates on Blackboard, which resulted in important documents being posted online without students' knowledge, is a case in point. More often, though, gaps resulted from *communication* or *process* failure. An example of *communication* failure would be when the instructor provided only vague details for an upcoming in-class assignment, and then students did not follow up to clarify the assignment or request more information. An example of a *process* failure would be when the members of a project group failed to thoroughly review the assignment guidelines and due dates, or neglected to assign clear responsibility for a particular component of the project.

The prevalence of limited awareness and the problems caused by gaps suggest the potential value of a complete, shared inventory of class work and deliverables. For example, a class wiki (that is actively maintained and used) could provide a central source of information to help make gaps more obvious and encourage mitigating behaviors (e.g., asking clarifying questions in class). If information was collected into well-structured systems and interfaces, students might be able to rely less on unreliable, informal channels, such as 'check-in' conversations with friends. Since gaps in awareness often affected students' understanding of project scope and deadlines, linking reminding information with project and task details might be particularly valuable.

Affect and Narrative

PIM is typically analyzed using neutral terms such as information, tasks, projects, files, and messages. However, analyses focusing on these areas ignore the impact of affective responses and processing, and the power of narrative to capture attention and structure memory. Emotional references during class sessions captured students' attention and interest, and generated discussion—they appeared to encourage active learning. The prevalence and influence of affect and narrative in this study suggest that future research can address questions, such as “How can PIM/CARPE systems exploit affective ‘milestones’ like laughter, surprise, or intense debate to facilitate retrieval, reflection, memory, and learning?”

For example, one design opportunity to explore would be the use of prompts in structured journaling or reflection interfaces to encourage students to incorporate emotions into their metacognition. A prompt such as “Identify a fact, story, or image related to this concept that you found especially happy, funny, sad, or surprising” might help students link biological concepts to compelling stories and emotions, bolstering their learning and memory.

Learning PIM

As discussed above in the section on collaboration, the results showed a substantial PIM skill gap between college students and experienced knowledge workers. In addition, although all the students I observed were generally comfortable with technology, there was a large variance in technology-related expertise and knowledge. For example, one student who participated in the MyLifeBits study regularly experimented with PIM tools such as Google Desktop and Google Applications, and was able to diagnose complex technical problems such as a flawed application using too much CPU time on her laptop. In contrast, another participant exhibited little knowledge of tools beyond standard desktop applications, and was extremely reluctant to explore alternative e-mail applications despite being frustrated with the UNC webmail interface.

This variance should encourage researchers and educators to look beyond simplistic characterizations such as "Net Gen students," (Gibbons, 2007) which often portray all contemporary students as equally adept at using technology to support educational and social pursuits. Many students have much to learn about how to use technology effectively to support their PIM activities. This finding is consistent with other recent research on students' technological knowledge and skills. As Gibbons and Foster (2007) observe:

> For example, we were all surprised at the extent to which students consult their parents and other family members about their academic work… We were also surprised to find that students are on average no more proficient with computer technology than are librarians and faculty members. Some students demonstrated broad knowledge of computers and facility in using them, but others were awkward and clumsy. And one of the biggest surprises was that many students feel enchained by that technology and struggle to break free, especially of instant messaging and similar distractions (p. 81).

Furthermore, it is worth considering that powerful tools often have lengthy learning curves—a fact often forgotten in discussion of PIM tool design. For example, all students at UNC "know how to use email," but there is a wide range of expertise within this specific task and application domain. Some students, including a "power user" I observed in BIO 101H, have learned shortcuts, such as keyboard accelerators that improve their efficiency when completing common tasks. Others have explored using customization features such as rules or filters, virtual searches, and custom views. Still others have extended their e-mail applications using additional software such as desktop search or application-specific extensions. PIM research has yet to characterize the difference in productivity between novice email client use and expert email client use (for a given email workload). But anecdotal evidence and everyday experience suggest the difference could be vast, and worthy of careful analysis.

Even more important than learning to use technology effectively in the service of PIM, is learning to "do" PIM effectively. As Spinuzzi (2006) notes, learning to manage information and tasks well becomes ever more important as education and working evolve:

> And because everyone is connected, because black boxes are in short supply and of short duration, anyone can potentially lay claim to another's time. Networks overlap and can be reconstituted unexpectedly, and the result is heavy work fragmentation. Workers must be able to adopt or adapt ways to deal with work fragmentation, including genres and rules that allow them to create their own stable transformations for prioritizing, organizing, and achieving work. That might involve learning popular time management techniques ... they certainly will involve examining, evaluating, adapting, and adopting the local innovations that coworkers have developed.

In an interview, Dr. DeSaix emphasized that "my role is much more the [soft skills such as] motivation and enthusiasm." That is, she feels it is critical to get students excited about biology, and believes they will learn much of the material on their own once they're motivated. I strongly agree with this perspective, but would extend it to include soft skills beyond excitement and motivation, such as PIM skills—information, time, and task management. Dr. DeSaix noted that, "if you came [to college] to play ball, you'd have a coach," and pointed out that learning skills centers can play a similar role by providing academic coaching. Given the evidence of even honors students' relatively weak PIM and collaboration skills, it appears there is a substantial opportunity for research on how to train students in PIM practices and strategies. A critical challenge for this line of research is how to encourage students to view PIM skills as intrinsically important and worth learning, rather than using institutional incentives such as grades and degree requirements to compel the study of PIM.

Social Information Management

Students' social networks are an integral part of their PIM activities—but reliance on peer knowledge often proved a double-edged sword. In some cases, it can be fast and effective to contact a classmate (whether in person or online) instead of relying solely on one's own PIM system. However, widespread student norms (such as 'minimize effort,' and 'study strategically') and inconsistent PIM skills can significantly alter the character of information accessed through a social connection.

Working with peers to explore concepts and question each other's understanding is a key metacognitive strategy for students. But while such social metacognition is valuable, it is often difficult to initiate. I rarely observed students discuss biological concepts directly. Rather, they entered into peer conversations using 'strategic' questions, such as, "Do you think she [the instructor] will ask about topic X?" While these strategic questions can potentially lay the groundwork for a more substantive discussion, in my experience students were reluctant to venture beyond the safe ground of analyzing what material would be covered on the test. They rarely questioned each other about specific biological concepts, or worked to expand each other's knowledge.

The most common and characteristic example of social PIM in practice was the 'informal check-in.' During idle times, such as when waiting for class to start, students would often casually ask each other about their progress on various assignments, readings, and so forth. Informal check-ins worked well for some students when referring to an assignment that everyone in the class was responsible for. For smaller group projects, however, this approach to social PIM was less effective, and gaps occurred more frequently. I surmised that the effectiveness of social PIM (at least for reminding and task management) depends on the size of the social network: one can rely on one's network *when it's big enough*.

Designers can likely facilitate social PIM with appropriate social tools. It should not be assumed, though, that online social networks will be appropriated for social PIM, simply because those networks are widely adopted and embedded in students' lives. While it is true that students are increasingly active in online social networks, the idea that these tools inherently provide rich support for social PIM may be misleading. I rarely observed students using online social networks such as Facebook for educational purposes, and few students in the class even identified which classes they were enrolled in on their Facebook profiles. In interviews, students described using Facebook primarily to have fun and relax. Moreover, online social tools are increasingly overloaded with functions, supporting activities as varied as dating, entertainment, and shopping, in addition to personal expression. Thus, while the online social networks are certainly worth exploring as design and research platforms, research should also examine how to improve the social PIM capabilities of other tools students regularly use, including courseware systems, e-mail, and IM.

The existence of widespread cultural or normative barriers to substantive social metacognition poses difficulties for the design of PIM systems that seek to support metacognition. As discussed previously in the section on collaboration, entrenched student practices threaten to make even powerful tool capabilities ineffective. At the same time, though, this dilemma opens up a new design space for PIM systems. Social PIM systems could potentially provide scaffolding for effective metacognitive learning by providing structures, prompts, and incentives to engage students in social metacognition.

Priority and relevance

Students are deluged with information. The textbook in BIO 101H alone provided enough text, questions, and activities to occupy a dedicated student for months, if not years. Indeed, a major focus of our class sessions was simply to direct students' attention to key areas for study. Jean frequently emphasized how the scope of the test was related to what she discusses in class—"if we talk about it in class, it's fair game."

In other words, identifying which information is most important and relevant is a key part of learning and studying processes, and critical to academic success. Students' PIM systems, however, often provide little support for these concepts of priority and relevance. How does one identify which of the many websites, documents, presentations, and other information inputs are worthy of one's attention and focus? These concepts are simply absent from key PIM tools such as file systems, e-mail clients, Blackboard, and bookmarks.

In general, tools seem to place too much focus on providing 'raw' information, and too little focus on making order and metacognition. Students have vast amounts of biology information at their fingertips, but that doesn't mean they necessarily study effectively or learn deeply. Analogously, students know how to use PowerPoint to produce visually rich slide shows, but this doesn't mean they can give a clear, concise, and compelling presentation. Overall, there appears to be a substantial design opportunity to rethink PIM systems with an eye toward relevance and priority.

5.1.2 Technology probe study

Research Question 2 asked, "How do students use the MyLifeBits system?" and "What are the user experience issues to be addressed in future designs?" Findings from observations of and interviews with students, as well as my own long-term experience using MyLifeBits, were used to consider the following questions:

- How do students use the MyLifeBits[6] system?
    - Is it effective and efficient in practice?
    - How do students structure their MyLifeBits store, and how does this structure evolve with use?
    - What are the user experience issues to be addressed in future designs?

In general, MyLifeBits was seen as a powerful tool for refinding. It was clear how MyLifeBits could support scenarios related to students' refinding behaviors. Moreover, MyLifeBits was perceived as less taxing and more pleasurable to use than standard refinding tools such as Web browser bookmarks. With additional refinement and integration, tools such as MyLifeBits could become a regular part of PIM systems' refinding support. In particular, MyLifeBits appeared to simplify students' PIM routines and reduce cognitive overhead by automatically capturing their Web browsing history and making it easily accessible. This always-on, automatic capture seemed qualitatively different than manual methods such as bookmarking a page.

The ability to browse visually through thumbnails was seen as particularly useful. Visual browsing extends typical refinding interactions (such as searching

[6] MyLifeBits is part of Microsoft Research's Digital Memories project (see http://research.microsoft.com/ur/us/fundingopps/RFPs/DigitalMemories_Memex_RFP.aspx).

through file names or text, or browsing through a hierarchy of files), enabling students to rely on their visual recognition system to identify and distinguish resources. The evidence that students found this visual interaction pleasurable and efficient supports and extends previous research on using thumbnails for Web-based IR interfaces (Dziadosz & Chandrasekar, 2002; Woodruff, Rosenholtz, Morrison, Faulring, & Pirolli, 2002). Considering this consistent pattern of support for visual browsing, PIM systems should incorporate these types of visual interactions whenever possible.

Research should also address how to provide visual representations for other types of resources besides Web pages and images. Visual refinding could also be enhanced by incorporating some elements of context, such as where a student was or who she was working with at the time a resource was captured and stored in MyLifeBits. Thumbnail browsing can also be improved in future designs by providing better visual representations of dynamic information objects, which have different implications for PIM than typical static objects, such as a simple document or image. In particular, students were frustrated by the numerous redundant thumbnail images generated when using dynamic websites such as an HIV genomics database. Future work can build upon initial results, which have showed promise in using automatic filtering techniques to limit redundancy in documents and emails (Whang & Gemmell, 2006).

In considering the possibilities for MyLifeBits as a platform supporting core PIM tasks, it is apparent that its strengths are in refinding. It currently provides little support for reminding and task management. Its collections, annotations, and ranking features offer great potential for supporting making order and even reflection, but the current implementation is limited in supporting students' needs. Future work should focus on extending MyLifeBits' support for these higher-order tasks.

In the area of making order, for example, there are many opportunities to extend MyLifeBits by enabling students to create personal knowledge structures that incorporate diverse resources such as email, class notes, tasks, and projects. Providing additional metadata, such as free-text tags, indicators of priority/importance, or subject-specific taxonomies, would support the construction of richer personal knowledge structures. In addition, it may be worth exploring how to incorporate alternative organizational forms—such as concept maps, mind maps, and diagrams—that can support students' learning processes. Finally, recent research has explored how to incorporate semantic information and links into desktop search systems (Chirita et al., 2005; Nejdl & Paiu, 2005). These models could also be used to extend MyLifeBits' capabilities.

MyLifeBits' support for students' collaboration practices is another area for improvement. While students were able to use MyLifeBits successfully to support group projects, they relied primarily on in-person group meetings to do so. Integrating online collaboration with MyLifeBits' PIM capabilities appears to have great potential. In addition, it is worth considering the widespread adoption of social resource-sharing systems, in particular del.icio.us and LibraryThing. Users of these systems voluntarily create rich metadata and annotations, a phenomenon some observers have called "enjoyable metadata" (Mangiafico, 2007). In contrast, users of MyLifeBits saw creating annotations as arduous and largely unnecessary. Future system design should seek to enable making order, not just as a technical capability, but as an engaging and rewarding experience.

5.1.3 Participatory design

RQ3 asked, “What design requirements and directions could improve a student-focused PIM system to facilitate learning, reflection, and metacognition?” A participatory design session conducted with students from BIO 101H identified a number of scenarios and specific design concepts that addressed some of students’ key PIM needs.

In general, students were most concerned with solutions to the problems of managing their workload for their classes, and collaborating with peers. Students’ concerns were therefore consistent with problems observed during the fieldwork, suggesting both that these concerns are real and that students are aware of them, at least to some extent. Students also identified self-management concerns, such as procrastinating by browsing the Web or Facebook, that were rarely observed during typical educational interactions such as class sessions and group meetings. These concerns illustrate the paradoxical nature (Mick & Fournier, 1998) of ubiquitous access to computers and high-speed Internet connections, which can both facilitate work and provide an infinite source of distractions.

5.2 Implications for Design

This research identified numerous scenarios that represent key PIM behaviors of undergraduate students. Current technologies provide only incomplete and fragmented support for many of these scenarios. The findings of this study indicate that a goal of future PIM design efforts should explore techniques for better supporting these behaviors, based on the identified scenarios. This section presents some initial design concepts that suggest alternative directions for PIM system design. The goal is to identify design opportunities that transcend conventional approaches to PIM—a goal in harmony with Sengers and Gaver's argument that "designers unconsciously design systems for work-related values such as efficiency … alternative values such as curiosity, play, exploration, and reflection are also important… and new design strategies are needed to design for them" (p. 101).

5.2.1 Design concept 1: Multimedia journal/e-Portfolio

User needs

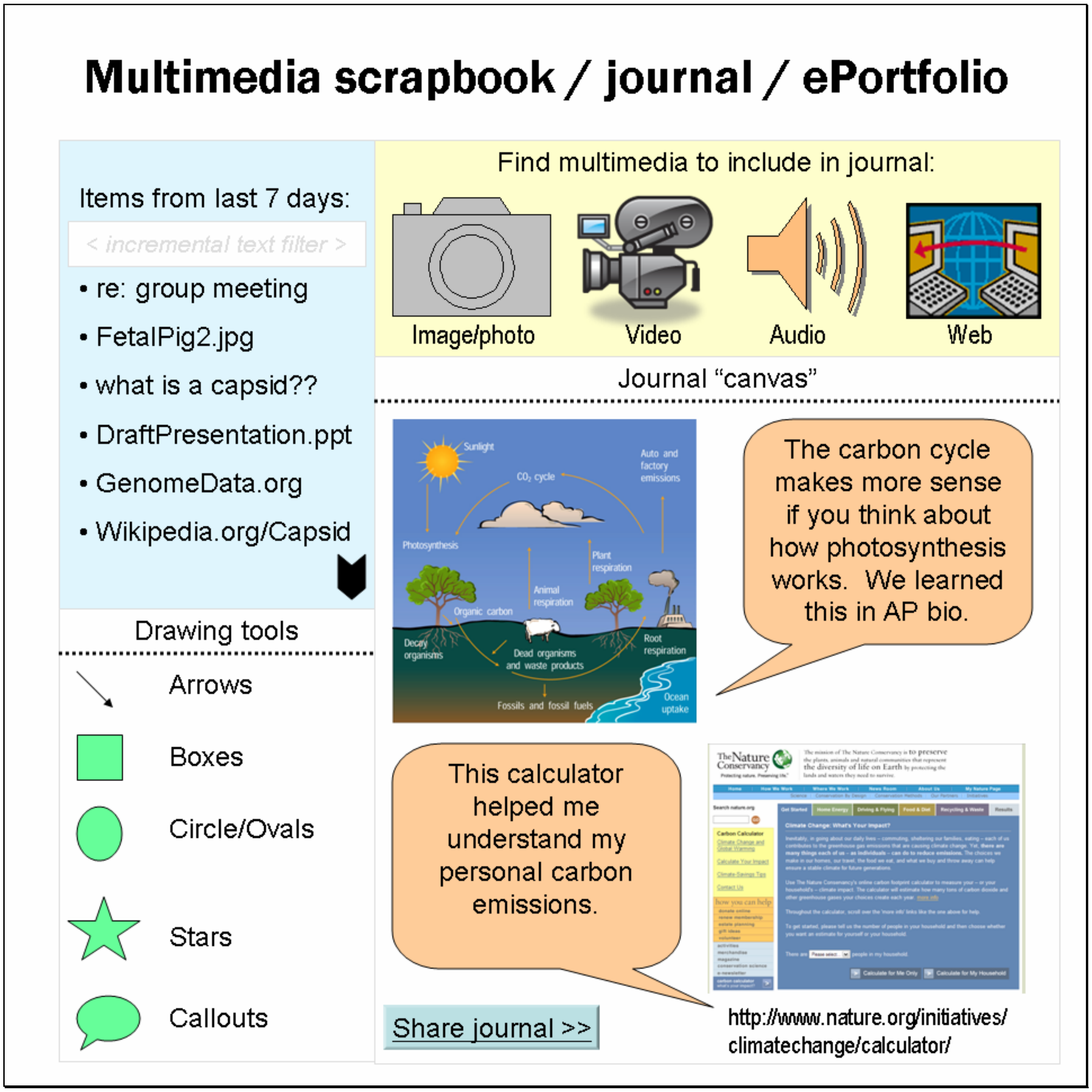
While students value the perspective and insights they gain by discussing their classwork with other students, they often find it difficult to do so in a meaningful way. Strong social norms appear to inhibit students from initiating activities or asking questions that could be perceived as too direct, or go beyond "strategic" questions such as "what type of questions do you think will be on the test?" Students would likely benefit from tools that provide alternative ways of initiating substantive, class-related conversations.

PIM Scenario

At the end of class on a Thursday, Peter's instructor reminds the students to complete their weekly review. Peter goes to a coffee shop to get a drink and complete his review. He opens his memex, and sees a week's worth of SenseCam images, documents, emails, photos, and audio related to his Population Ecology class. He browses through the collection, selecting artifacts that strike him as particularly memorable, useful or interesting. He is able to quickly combine these artifacts into a multimedia diary of his week's learning. Finally, Peter selects "share journal," picks a classmate from a list provided by the system, and sends his diary entry to that person. He receives his classmate's responses in return, and they begin chatting about what confused them in class.

Design concept

Figure 29. Design Concept #1: a multimedia scrapbook/journal/ePortfolio.



This design concept (see Figure 29) illustrates three key functions designed to support students' reflection and metacognition. First, students are able to browse and access resources (documents, presentations, Web site, etc.) that they have used recently. This form of browsing is intended both to help facilitate students' recognition of topics and concepts they may wish to reflect on more fully, and to provide rapid access to supporting resources.

Second, a free-form "journal canvas" enables students to construct a multimedia composite with much greater flexibility than a typical text-centric editor, such as a word processor or email client. The multimedia journal is intended to help overcome the norms and practices that inhibit students' class-related conversations, by encouraging them to rely on visual processing and imagination instead of analytical processing and reasoning. Finally, a "share journal" button enables students to easily share the composite journal entry with classmates, promoting a process of social reflection .

5.2.2 Design concept 2: Social awareness dashboard

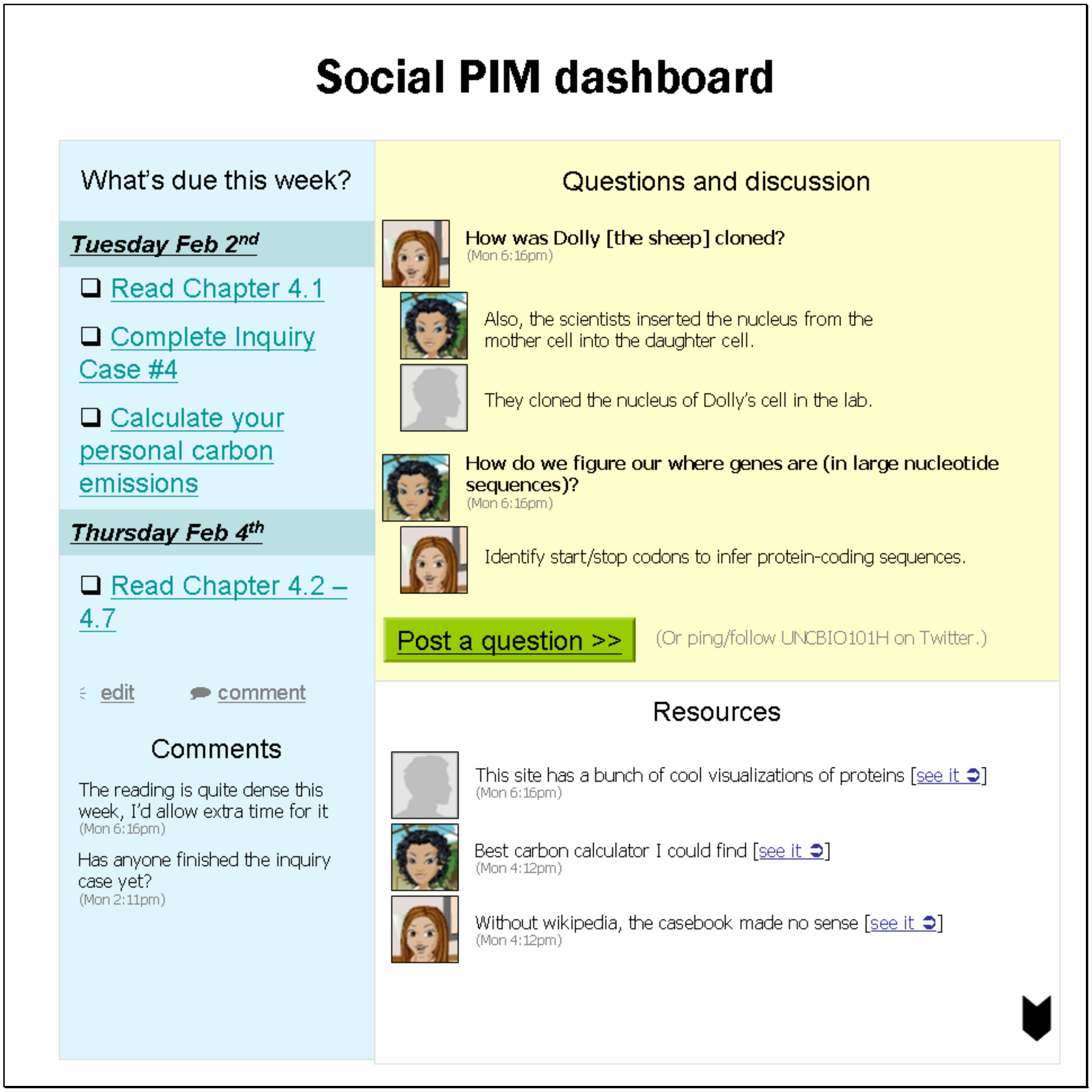
User needs

In practice, I found that developing a shared awareness of what others (peers, instructor, students) know, understand, and feel was highly problematic. Gaps occurred regularly, leading to stress, low-quality work, and reduced learning. These gaps were apparent in both instructor-student communication, and among students working in groups.

Scenario

Jonas goes to the library to study after class, and opens up his laptop. He wants to see a quick overview of the assignments and meetings he has coming up this week. He sees that his presentation (with his partner, Rick) summarizing their research on induced cell death is due soon. He is able to easily share with Rick a diagram of cell death he has created. As they chat online, they realize they are both confused about how induced cell death is triggered, so they post a question to the class. A few minutes later, their classmate Anna sees the question and suggests a Web site she found helpful.

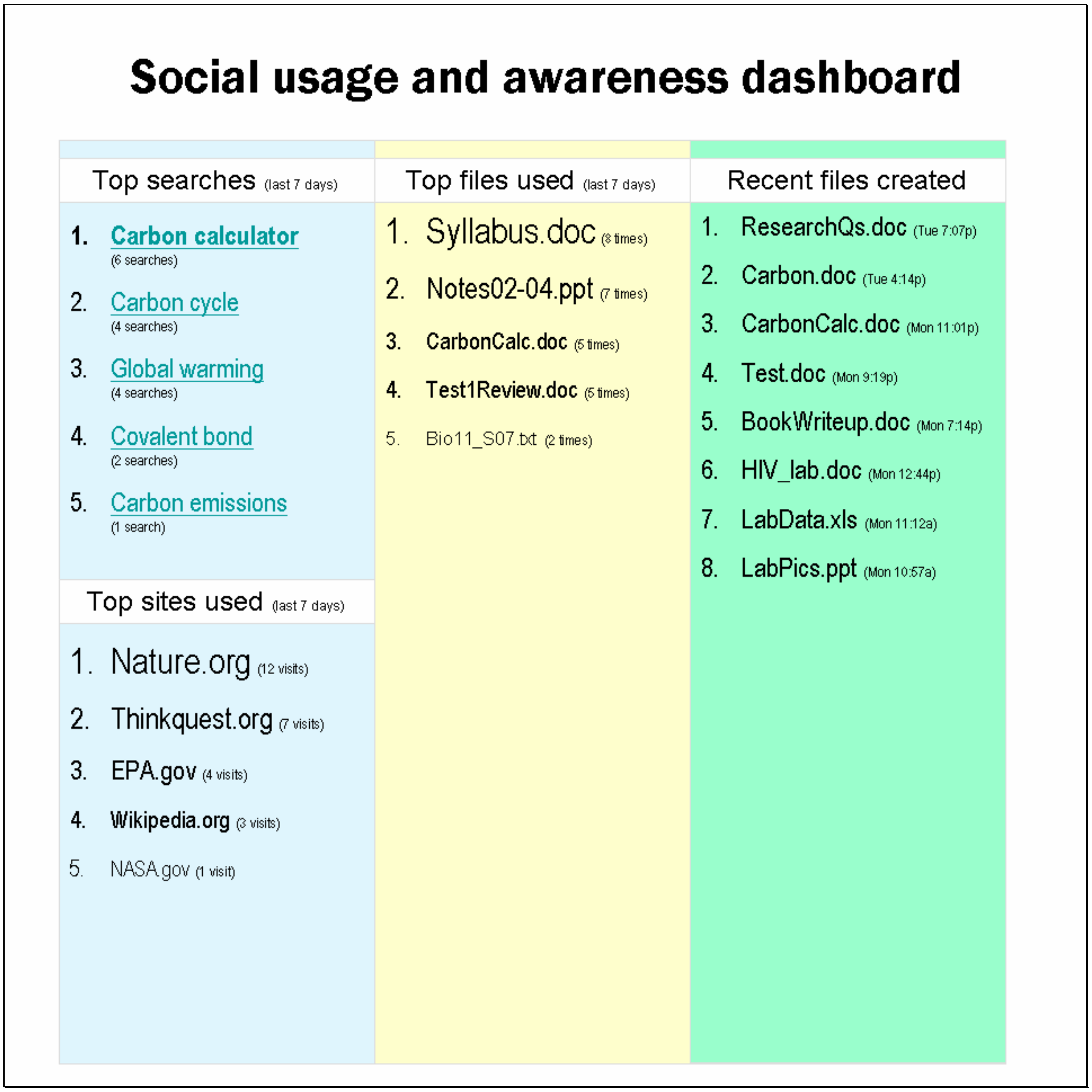
Figure 30. Design Concept #2a: A social PIM dashboard.



This design concept (see Figure 30) shows two features that could help address students' awareness challenge. First, a summary of "what's due this week" is visible to and editable by any student. Unlike a fixed syllabus, this summary can evolve based on students' understanding of what is due and what is required for each assignment. Students can also comment on this shared view.

Second, a simple question-and-answer forum enables students to post brief questions and receive answers or suggestions for resources (images, document, Web sites) from their peers. This forum provides the option of anonymous posting, so students can escape embarrassment when asking a seemingly simple-minded question. Finally, students can choose to link to the forum using a social messaging service, such as Twitter or Facebook, which provide the flexibility to receive messages through IM clients or cell phones.

Figure 31. Design Concept #2b: Social usage and awareness dashboard.



The second design concept for social awareness (see Figure 31) emphasizes how viewing recent activity of other's work can provide cues as to what is important in the class. The value of shortcuts to recently-used files for individual PIM tasks has been demonstrated through research with knowledge workers (J. Tang et al., 2007). While having a display of recent co-worker activity could be overwhelming in a large organization, the dashboard is likely to remain usable in a small class.

Tee, Greenberg and Gutwin (2006) describe “artifact awareness” as “one person’s knowledge of the artifacts and tools that other people are working with” (p. 99). The design concept shown here applies the recent-usage paradigm to the social environment of a class, providing the benefits of “artifact awareness,” which include monitoring and coordinating a collaborative task, triggering interest in another person’s activity, determining how busy others are, and creating serendipitous opportunities for conversation and social activity (Tee et al., 2006). This concept could also potentially be extended to display applications and tools that other students are using.

This design assumes that some technology is available to distinguish the searches, files, and visited sites that are relevant to the class. Providing interfaces for students to tag their resources, automatically matching application activity to a particular class using task tracing (Dragunov et al., 2005), or using context-awareness techniques are potential approaches to this challenge.

5.2.3 Design concept 3: Social reflection tool

User need

Education and learning science research strongly suggests that reflecting on what one has been learning in a class stimulates metacognition and active learning, leading to more engaged students and ultimately to better understanding. However, in practice students rarely initiate reflective activities on their own, so they rarely engage in metacognition or receive its benefits.

Scenario

Sarah attended a small rural high school, and had a less-rigorous high school biology education than many students in her introductory college class. She often feels confused in class, and isn't confident enough to interject her questions into class discussion. She checks her favorite social networking site every day after her last class. Some days, she sees a prompt to answer "What did you find confusing in our last class?" She feels relieved when she's able to express her uncertainty and lack of understanding by responding to this question.

Design concept

Figure 32. Design Concept #3: Social reflection interface.

While Design Concept 1, the multimedia journal, links individual reflection with social sharing, this concept (see Figure 32) emphasizes the value of integrating reflection into students' day-to-day activities. Time for reflection and metacognition is often given short shrift amid students' hectic schedules and continual deadline pressure. Rather than exhorting students to spend more time reflecting on what they are learning, this design concept attempts to prompt reflection by fitting into the stream of digital activities in which students naturally engage. The particular approach illustrated here suggests a proxy account ("Bio101Reflector") on a social networking tool such as Facebook, but any system which students regularly use for educational activity could be adapted to this purpose.

5.2.4 Design concept 4: Personal reflection tool

User need

In the participatory design session, students noted that they spend significant amounts of time on entertaining, non-academic activities such as surfing the Web, browsing profiles on Facebook, or watching TV. They become aware of how much time these activities consume when deadline pressure forces them to focus exclusively on a particular academic project, an insight that can lead to the desire to better time management. Without more regular attention to time use, however, these periodic insights are unlikely to lead to significant behavior change.

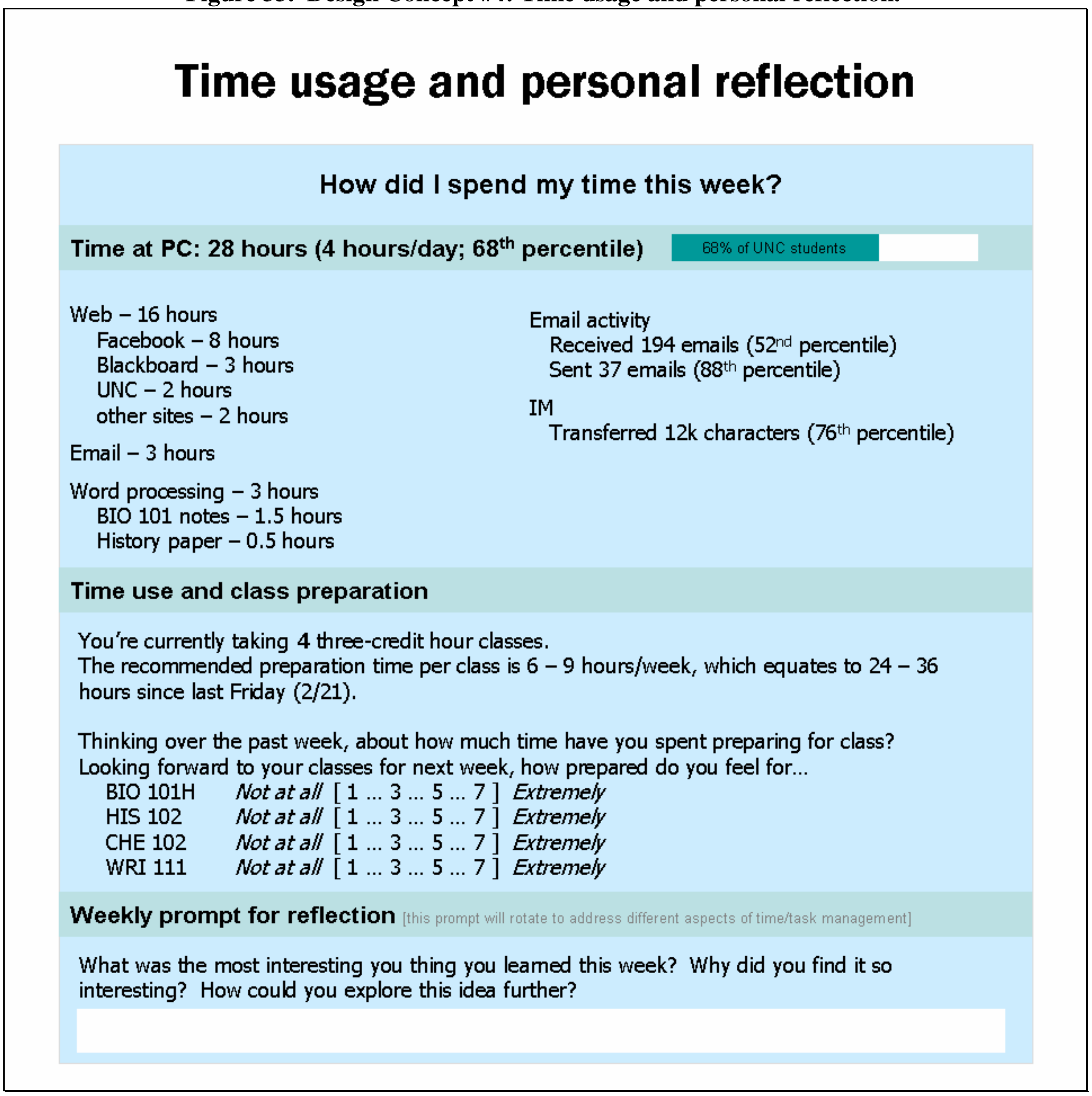
Scenario

After receiving his grades on his midterm exams and projects, Ian is disappointed in his performance. He wants to use his time in the second half of the semester more effectively so that his final grades are a letter grade higher than his current grades. The first week back in school after spring break, he is able to review major activities he spent time on, and compare his time use to other students at his school. He realizes that even though he was motivated to study this week, he still spent much more time than he had thought browsing

Facebook and sending email to friends. He decides that next week he will set aside two blocks of time to study in the library without a computer, so he can focus on carefully reading his lab manual, which he often finds confusing.

Design concept

Figure 33. Design Concept #4: Time usage and personal reflection.



This design concept (see Figure 33) integrates techniques from commercial time-analysis tools (RescueTime, TimeSnapper) with the idea of "feedback analysis," taken from studies of expertise and managerial performance. Both psychological studies of expertise (Ericsson, 2007) and popular management books (Drucker, 2002) emphasize the value of regularly reviewing how one has spent one's time, the effect of recent decisions, and lessons that have been learned. This design concept is intended to help students learn these practices by prompting them to review their time use, compare it to their peers, and assess their preparation for class. In addition, this concept incorporates a weekly prompt for personal reflection, which could change each week in order to introduce students to a range of issues.

This concludes Chapter 5, "Discussion." The following chapter concludes the dissertation.

Chapter 6: Conclusion

This dissertation investigated the personal information management (PIM) behaviors and practices of undergraduate students, in order to enable the design of PIM systems that can improve their education. Two complementary field studies and a participatory design session were designed and conducted to support this investigation. First, an ethnographic field study, involving four months of immersive participant observation research in an undergraduate biology class, was designed to gather extensive qualitative data on students' day-to-day PIM practices. Second, a technology probe, using the MyLifeBits system from Microsoft Research, was designed to explore students' use of a next-generation PIM system and to identify new directions for design. Data from the participant observation and interviews conducted with students, along with the participatory design session, were used to develop design concepts for PIM systems that can both simplify students' information management, and support active learning.

The unifying purpose of this research was to gather data that could inform the design of educational technology, enabling students to learn in new ways, with less overload and stress. The findings have the potential to improve PIM systems for students, and enable new forms of support for learning activities, such as reflection and metacognition. The key findings of this research, and its specific contributions to PIM research, theory, and methodology are summarized in the subsections that follow.

6.1 Summary of findings

This research investigated undergraduate students' PIM behaviors and practices, their use of MyLifeBits system features, and opportunities for improving the design of PIM systems for students.

6.1.1 Key findings regarding students' PIM behaviors and practices

Immersive ethnographic research in an undergraduate biology class led to several insights into students' PIM behaviors and practices, including the following:

1. Students engage regularly in project management activities, and a key challenge for them is managing projects and tasks, as opposed to managing information only.
2. Students' work can be highly collaborative, but the tools that students were observed to use in this study offered only minimal support for collaboration.
3. Students were observed to have difficulty with core PIM activities, such as managing tasks and reminders. Managing information can be challenging for students, even when they are comfortable with specific

technologies and tools. PIM and technical skills vary widely among students.

4. Students must manage a diverse array of information resources—including many distinct formats, applications, and media—which are rarely integrated.
5. There can be gaps—ranging from obvious to subtle—in understanding and awareness among students and instructors. These gaps influence what information students capture and manage in their PIM systems. In some cases, these gaps can lead to frustration, stress, and reduced academic performance.

6.1.2 Synthesis of task-based and thematic analyses

This study integrated two analytical approaches to students' PIM behaviors: task-based analysis, using the four core PIM tasks (refinding; reminding and task management; making order; reflection and metacognition) and thematic analysis (using the eight themes identified by inductive analysis of the field data). Table 20 (following page) combines these two approaches. It provides an overview of the eight themes, compared to the framework of four core PIM tasks. The cells in the table provide examples of observations that link a particular task and theme. Blank cells indicate tasks/theme combinations where clear exemplar cases were not observed. This juxtaposition indicates how the identified themes in students' behaviors and practices are connected to the core PIM tasks, and provide concrete examples of the tasks based on direct observation and experience.

Table 20. Comparison of observed themes in PIM behavior, as related to core PIM tasks. Each cell in the table represents an example behavior relevant to a particular theme and a particular task.

THEME ⇉	TASKS / PROJECTS				CONTENT / LEARNING		INFO. ACCESS	
TASK ⇊	*Project manage-ment*	*Collab-oration*	*Dynamic, evolving task structures*	*Shared aware-ness / gaps*	*Affect and narrative*	*PIM as learnable skill*	*Social Info. Man-agement*	*Priority and relevance*
Refinding	Review Black-board for assign-ment in-formation.	Shared review of captured web pages in MLB.	Instructor changes assign-ment scope in class.			Student learns MLB, and compares to Google Desktop.		Instructor says "you don't need to write this down."
Reminding & task manage-ment		Ambigu-ous meeting plans/next steps.	Make note in paper planner re: due date.	Students missing planned group meetings.		Instructor encour-ages stu-dents to check Black-board regularly.	Email to class to clarify assign-ment.	
Making order	Create collection of project files in MLB.				Students take notes in class re: funny or sad story.		Asking others in study session what to review.	Instructor sets scope of test in class dis-cussion.
Reflection & meta-cognition				Instructor surprised when assign-ments not received.		Reflecting on own PIM strategies and sys-tems?		Study group: "What do you think she'll ask about this?"

6.1.3 Key findings regarding students' use of MyLifeBits

Six participants experimented with MyLifeBits, and four students continued to use it for several weeks as part of their academic work. Interviews and observations with these students indicated that:

1. MyLifeBits supports a more visual, browsing-oriented form of refinding than students' typical PIM tools. Participants found the MLB mode of refinding easy to use and effective.
2. MyLifeBits has the potential to support making order and reflection in new ways through capabilities such as annotating resources and building collections, although participants found the current design of these features difficult to use, and did not use them regularly.
3. Participants generally did not use MyLifeBits to support their reminding and task management.
4. Specific elements of the MyLifeBits user interface could likely be improved to support efficiency during regular use.

6.1.4 Key possibilities for future design of PIM systems

Based on the ethnographic investigation of students' behaviors and practices, and the group participatory design session, several directions for PIM system design were identified. This research strongly suggests that PIM systems could help to support students' needs using the following approaches:

1. Incorporate social awareness and communication into PIM systems, to help reduce gaps in understanding and to facilitate reflection.
2. Integrate collaboration technologies into PIM systems, to support students' highly collaborative work practices (such as group research projects and study sessions).
3. Provide tools to stimulate reflection (e.g., personal analytics) and create reflective artifacts (e.g., journals, multimedia scrapbooks).
4. Shift the focus of design to the outcomes (such as, "getting my assignment done on time, and in the way the teacher expects" or "preparing to get a high grade on the test") that PIM supports rather than the PIM process itself.
5. Encourage meta-level behaviors, such as examining one's own PIM system and structure, to scaffold students' learning of PIM skills—including metadata creation, project analysis and management, collaboration, and reflection.

6.2 Theoretical implications

Previous PIM research has been largely atheoretical, focusing on identifying specific strategies (e.g. "filing" versus "piling" in e-mail management) and breakdowns (e.g. information fragmentation across e-mail, documents, and web pages) (Bellotti et al., 2005; Bergman et al., 2006). More extensive behavioral and conceptual research is clearly needed to build rigorous theories of PIM. The present research can inform two possible models that could contribute to the development of PIM theories.

6.2.1 Dual-process models

In this research, it was observed that students often appeared to make "low-cost" decisions when completing PIM tasks. That is, students used quick rules of thumb or habits, rather than more complete cognitive processing and analysis, to manage information and tasks. These "low-cost" techniques were seen in an array of different activities. Some students reflexively wrote assignment-related information provided in class in a paper planner, regardless of whether the planner was likely to help them keep track of the new information appropriately. Students were regularly observed to rely on project group meetings as a way to move projects forward, and to ignore the need to communicate about and work on projects between meetings. Students were also seen to use deadlines as part of their rules of thumb for prioritizing work, often disregarding important project management and planning activities until an urgent deadline made these activities salient.

"Dual process" models, developed in cognitive and social psychology, have been used to model just these kinds of behaviors. In many situations, people make decisions by "satisficing," choosing an option that is "good enough" rather than optimal. Satisficing has been recognized as a key factor in individuals' PIM behavior (Barreau, 1995). The essence of dual-process models is that people evaluate the available options on the basis of peripheral cues (such as ease of access or attractiveness) and rules of thumb ("heuristic processing"), rather than by careful elaboration ("systematic processing") (Chaiken, 1987). In other words, people exhibit "bounded rationality," not pure rationality. Bounded rationality been applied to information-seeking behavior and HCI in the "information foraging" model (Chi, 2003). It appears that dual-process models and bounded rationality may be promising foundation for PIM theories as well.

Figure 34. PIM behavior from dual-process perspective.

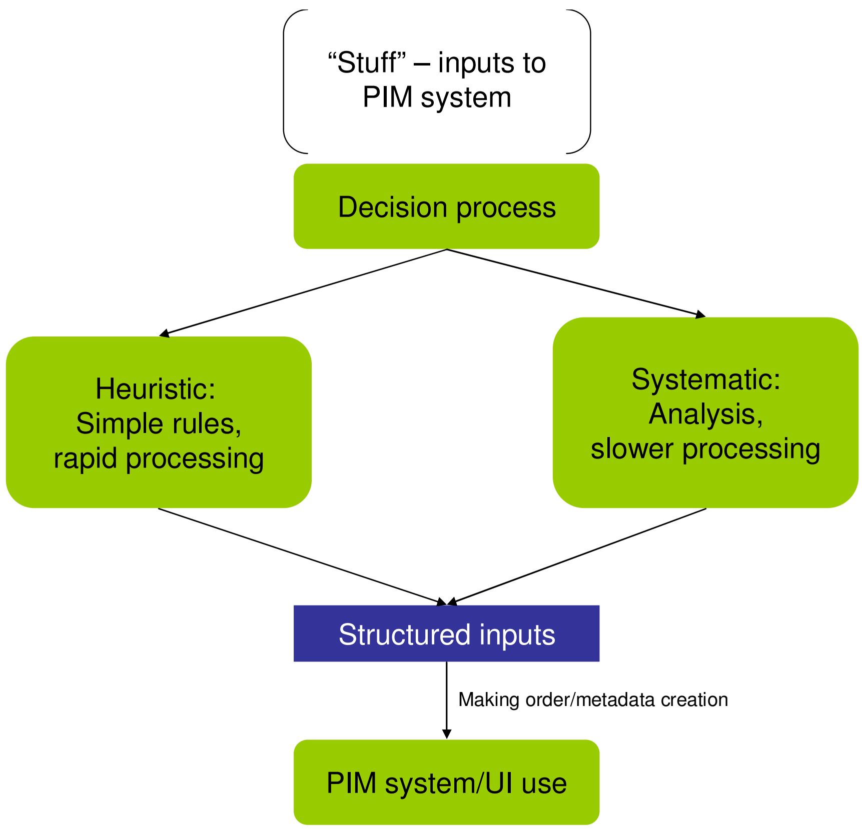


Figure 34, created to illustrate this point, provides an application of the dual-process model to PIM behavior. In this model, individuals make decisions about how to process information as they receive inputs that could potentially be stored in their PIM system. According to their individual needs and context, they then apply either a simple rule (heuristic processing) to the information, or they analyze the information more thoroughly (systematic processing).

For example, a student might apply a heuristic such as "whenever a teacher gives out a due date for something, write "X is due" on that date in my paper planner." After meeting with other students in a project group, this student might find that this heuristic is insufficient, as it is not clear what the "due date" is on the self-defined work of contributing to the group. So she would shift into systematic processing, breaking down the project assignment making sure she understands her contribution to the group. Exactly what prompts students to engage in systematic rather than heuristic processing is unclear, so understanding and delineating these cognitive processes is an open area for research. Analogous work on students' information-seeking behaviors (Fast & Campbell, 2004; Head, 2007; Looker & Thiessen, 2003) could inform such analyses of cognitive processes in PIM. Overall, more developed models incorporating an understanding of heuristic and systematic processing could greatly improve the rigor and explanatory power of PIM theories.

Regardless of which processing mode is employed, the individual still needs to structure her inputs to the PIM system. This activity could be as simple as writing a note in a paper planner, or sending a quick email to a classmate. But in some cases, the structuring process could be quite involved—e.g., creating a plan for a term-length research project involving multiple people and deliverables. The key point is that these individual PIM activities of processing and structuring information have the potential to strongly influence the users' interaction with the PIM system and UI. PIM systems should therefore be designed to support users' processing and structuring activities.

6.2.2 PIM practices and education

In this research, I found that students in BIO 101H had many difficulties with common PIM activities, ranging from managing email to handling file versions and names, to arranging and running meetings, to coordinating group projects. Students frequently coped with gaps in their awareness and understanding of assignments and projects, which in some cases led to missed assignments as well as feelings of stress and overload. These findings suggest that a second opportunity for PIM theory is to broaden the scope of PIM research beyond system design and engineering, by treating *practices* and *education* as central to PIM effectiveness.

The importance of practices and education can be seen in analogous research areas, such as IR—in particular, Web search engine research. Many innovations—such as TF-IDF ranking, improvements in Web crawlers, and link analysis algorithms such as PageRank—have all contributed to enormous improvements in Web search quality. But, even as technology has advanced, the *practices* of Web site creators have still remained critical to search effectiveness. Today, these practices include creating well-structured HTML based on semantic tags, writing descriptive page titles, constructing clean, meaningful URLs, and acquiring inbound links. Without such practices, even powerful Web crawlers and sophisticated ranking algorithms don't work nearly as well. A second example is that these improvements in Web search technology may do little to improve the information-seeking effectiveness of users who have limited information literacy or technological proficiency (CIBER, 2008; Horwath & Williamson, 2008).

The same need for *effective practices* can be seen in PIM. It is now technically feasible to record vast amounts of personal information in integrated systems such as MyLifeBits. That doesn't mean, however, that one's information is processed and structured in a way that is personally meaningful, or that one uses it effectively. This discrepancy may be particularly relevant in the educational domain. The notable difference observed between the most and least productive students suggests the demands of college work alone (group projects, deadlines, rigorous tests, etc.) may not instill effective PIM and self-management practices. Research should consider the wide variety of student PIM behaviors, and try to find ways to identify highly effective PIM practices. Designers can then design systems that support these practices elegantly. Even better, research could identify ways to design systems that *encourage* people to adopt productive practices.

Among the most important points to consider is that PIM researchers should view the "problem" of PIM holistically, with the goal being to improve people's productivity and effectiveness—not just to design better systems. In particular, this research suggests that an assumption common to PIM research could be revised in two ways to stimulate new approaches:

- Assumption: Individuals' PIM practices are well-adapted to their needs and context, so we should design systems to match those practices (Bellotti et al., 2004).
- Counter-assumption 1: Many practices are habitual, not optimal. We should investigate the best practices, and find ways to help people adopt them.
- Counter-assumption 2: System design could help people modify their own practices, not just support existing practices.

Within this more holistic perspective, new theoretical approaches to PIM could also be developed and tested. For example, initial work on developing a theoretical analysis of GTD (Allen, 2001) suggests that cognitive science theories, particularly *distributed cognition* and *stigmergy*, may be relevant to our understanding of PIM processes and practices (Heylighen & Vidal, 2007). Distributed cognition (Kirsh, 2005) emphasizes that "the brain can 'offload' information and store it an external memory that is more reliable and less energy consuming than its own working memory… cognition is *distributed* across the brain and various material supports" (Heylighen & Vidal, 2007). Stigmergy (Elliott, 2007; Susi & Ziemke, 2001) is defined as making changes to or marks on an environment that cause an agent to perform work. Stigmergy is proposed as a theoretical framework for understanding Web-based collaboration (Elliott, 2007). Future work should seek to apply these promising theories to PIM behavior and system design.

6.3 Contributions to PIM methodology

This study makes three primary contributions to the methodology of future PIM research: a framework of PIM tasks for examining research questions and analyzing results; an understanding of the value of participant observation research for PIM; and an understanding of the use of personal capture/archiving systems such as MyLifeBits for PIM. Each of these three contributions are discussed below.

First, this research *developed and applied a framework of core PIM tasks*: refinding; reminding and task management; making order; reflection and metacognition. This framework synthesizes previous research on PIM behaviors from research areas including human-computer interaction, cognitive psychology, and information science. The framework was found to be an effective analytical tool for both examining longitudinal data from both the ethnographic field study, and the technology probe study. PIM researchers and system designers can use the framework to identify research questions, to structure and analyze behavioral data, and to explore new possibilities for design.

Second, the findings from the fieldwork component of this research *demonstrate the value of participant observation research* (grounded in an ethnographic or ethnomethodological perspective) for PIM methodology.

Solomon (2007) has identified six primary benefits of ethnographic approaches for HCI and interaction design:

1. Showing what people say they do versus what they *actually* do.
2. Exploring *cultural norms*.
3. Identifying *unmet needs* and seeing what's missing.
4. Identifying *product and service opportunities*.
5. Showing how *small things can have a large impact*.
6. Explaining abstract beliefs.

These benefits were apparent over the course of the ethnographic research conducted in this study. I was able to observe students' *actual* reminding and task management practices, which were often grounded in social interaction, as opposed to what they might have reported about maintaining planners and lists. *Cultural norms*, such as not asking too directly about difficult biology topics, emerged through exposure to study groups and students' informal interactions. *Unmet needs*, such as prompts for reflection and metacognition, were identified. *New opportunities* for the design of tools and services, including social awareness, were uncovered. And *seemingly small issues*, such as the layout and interaction of the Blackboard announcements page, were seen to have a large impact. Overall, the ethnographic approach was found to yield new insights into PIM behavior, and should be considered a key method for future PIM research.

Third, this research *tested the use of a capture and retrieval system* (MyLifeBits) as both an instrument and an object of study in PIM. Student participants used MyLifeBits regularly, which provided insights into how well it supports their PIM activities. At the same time, the information that students captured in their MyLifeBits store (such as class files, pictures, and so forth) acted as a kind of diary, providing insight into their learning, reflection, and metacognition behaviors. Exploiting the powerful capture capabilities of PIM systems such as MyLifeBits is also a promising avenue for advancing PIM methodology.

6.4 Limitations and future research

6.4.1 Limitations

The sample in this study was a single undergraduate class, BIO 101H. This approach enabled intensive interaction with students and the instructor in the class, ultimately involving over 150 hours of direct participant observation. A limitation of this approach was that it did not examine different educational domains (e.g., a sociology class) or different types of students (e.g. upperclassmen, professional school students, or doctoral students). In addition, this study focused primarily on interacting with students during educational activities, such as classes, study sessions, and project group meetings. As a result, little data was gathered on students' information behavior during other activities, such as extracurricular activities, or while socializing in dormitories. Students may exhibit different PIM behaviors and practices in these settings.

While students were able to use MyLifeBits for several weeks—much longer than a typical usability study—they appeared to still be learning the nuances of the system at the end of the semester. MyLifeBits seemed to not be fully integrated with their day-to-day PIM practices, and students did not make extensive use of MyLifeBits' advanced features, including annotations and collections. In part, this was because MyLifeBits didn't integrate with all of participants' applications, especially email. However, this lack of integration did enable comparison between students' use of MyLifeBits and their use of other PIM applications such as email clients and Windows Explorer.

While the participatory design session appeared effective at eliciting design ideas and concepts from students, it proved difficult to get students to relate specific scenarios and use cases that could guide the collaborative design process. Despite these limitations, the participatory design approach provided important insights on the scenarios and design directions students considered important. Future design sessions can address some of these limitations by providing more detailed examples or templates that would encourage students' design thinking without limiting their creativity.

6.4.2 Directions for future research

This dissertation sought to help move PIM research in new directions by emphasizing ethnographic fieldwork and a technology probe, in contrast to previous research based on less-intensive research methods such as interviews, surveys, and usability studies. It is hoped that future research can build on this work, and extend the findings, by examining new domains and user groups, by incorporating the methods tested here, and by exploring new approaches to PIM system design. The following subsections explore potential research directions in each of these three areas.

Domains and Users

Researchers can conduct ethnographic field studies in different domains than education. Possibilities including professional and managerial "knowledge work," (Halverson, Erickson, & Ackerman, 2004; Sellen et al., 2002), specialized technical fields such as medicine or engineering (Trigg et al., 1999), and non-professional domains such as home life (Taylor & Swan, 2004, 2005). In addition, because of the strong interplay between PIM and education, there is great potential for applying research methods and findings from learning science to PIM. Applying findings from PIM research could also improve STEM (Science, Technology, Engineering and Mathematics) education, as STEM initiatives have typically focused on improving classroom activities and interaction.

By drawing on methods from fields such as social psychology, organizational behavior, and health behavior, PIM researchers could assess the effects of changing PIM practices on individual and organizational productivity. As a simple example, consider a longitudinal study of the effects of adopting practitioner PIM methods, such as "Getting Things Done (GTD)" (Allen, 2001) or "Bit Literacy" (Hurst, 2007). Such a study would likely yield many insights beyond existing research, which has taken participants' existing practices as given. The results could contribute both to our understanding of effective PIM practices, and inspire design opportunities for systems to support these practices. This process is already well underway among practitioners, as there are numerous Web and software applications designed to support GTD and related methods (e.g., Nozbe.com, Vitalist.com). Since these methods and applications are rarely (if ever) systematically and rigorously evaluated, however, there is ample opportunity for research in this domain.

Methodology

Future research could explore further methodological innovations. It is likely possible to develop effective research methods that make more extensive use of automatically captured information to study people's PIM behaviors in natural settings. Methodological work in cognate disciplines such as social psychology and health behavior suggests that using automatic capture technologies effectively could spur significant innovation. For example, use of the Electronically Activated Recorder (EAR) has yielded fresh insights into differences between men and women's speech patterns, among other areas (Mehl, 2007; Mehl, Pennebaker, Crow, Dabbs, & Price, 2001). These types of automatic capture technologies could be used to understand how people capture and organize many different types of information, across different media.

HCI researchers have also identified the need for better support for diary studies and related field methods (Brandt, Weiss, & Klemmer, 2007; Carter & Mankoff, 2005). In this study, having access to MyLifeBits' archive of browsed web pages facilitated interviews with students, helping them to remember specific instances of refinding and collaboration behaviors. In addition, the GUI Logger component provided a measure of how frequently participants' used MyLifeBits. In future research, use of MyLifeBits and similar PIM tools as a research instrument could potentially transcend diary studies by building a comprehensive and searchable archive of participant information. For example, longitudinal studies using the GUI Logger (or emerging commercial tools, such as RescueTime (http://rescuetime.com/) could provide detailed analyses of how students spend their time. Of course, such studies would have to be carefully designed to avoid infringing on participants' privacy.

Research can also seek study PIM practices and education—particularly those related to project management, collaboration, and reflection—rather than tools. As Dourish (2006) has noted, an overemphasis on identifying "implications for design" has often limited the classes of insights drawn from qualitative field studies. By refocusing on PIM as human behavior, rather than tool usage, researchers could develop fresh approaches than ultimately inspire fundamentally different types of tools.

PIM System Design

Designing and evaluating these new types of PIM tools is also an important area for research. This study has suggested three main types of tools that warrant exploration. First, tools that provide *structured workflows* for PIM activities could help students and other types of users who are overwhelmed by inputs and struggling to cope with fragmented information. Structured workflows could help users process and organize their personal information using consistent approaches. For example, a "meeting tool" could help students establish an agenda for a meeting, record what happened during the meeting, and identify who is responsible for getting the work generated by the meeting accomplished.

Second, tools that *integrate social networking and social media* concepts with PIM could help improve students' awareness and reflection. Research on group awareness has shown how tools that provide cues to co-workers' tasks improve productivity and reduce information gaps (Tee et al., 2006). Providing analogous tools for students that take advantage of students' existing comfort with social networking applications could help them communicate and study in new ways, while reducing feelings of stress and overload. Third, tools that *incorporate affect and narrative* could help students organize information in new ways, and learn more effectively. For example, the Affective Diary (Madelene et al., 2006) combines sensor data with a user's journal entries to encourage new forms of reflection and personal expression.

6.4.3 Conclusion

Personal information management is central to education, work, and life in the "Information Age." People increasingly spend much of their working lives capturing, organizing, finding, and using information with their personal systems. Nevertheless, current PIM systems and technologies implement an extremely narrow vision of PIM tasks. This research developed a thematic analysis of students' PIM behaviors which provides a rich foundation for designing PIM systems and methods that can improve PIM effectiveness. In particular, improvements in PIM systems and methods can improve students' educations by encouraging active learning and collaboration, and by helping students prepare better for complex, collaborative work in graduate school and the workplace. My hope is that within a few years, new types of PIM technologies, grounded in understanding of people's needs and practices, will emerge to dramatically accelerate personal productivity and effectiveness.

Appendix A: Technology probe interview guide

Individual, semi-structured interviews were conducted with all participants in the technology probe study. The following questions and prompts were used to guide the interviews. The focus was on achieving an understanding of the student's PIM tasks and needs, so the interview evolved naturally according to what interests the participant expressed.

1. Can you walk me through some ways in which you've used MyLifeBits?
2. Tell me about how you used [within MyLifeBits]...
    - Browsing Web pages
        - Lists
        - Thumbnails
    - Search
        - Filters
            - Date
            - Type
            - Path
    - Type
    - Annotations
        - Text
        - Ranking
    - Collections
3. Blackboard

   a. How often do you check Blackboard?
   b. What areas of the site do you go to when you log on?
4. Facebook
   a. Have you used Facebook as part of this class or other classes? If so, how?
5. Other tools
   a. Can you show me any other Web sites, software, etc. you often use?
   b. What are problems or annoyances you've experienced with these?
6. Can you show me some of the ways in which you might…
    - Keep track of an assignment for class (e.g., Prof DeSaix says, do the following by next Tuesday?)
        - Keep track of what you have to do for a group project?
    - Keep track of a meeting with your project group?
    - Plan to study for a test or final exam?
        - Find someone to study with/set up a study group?
    - Organize your files for classes?

- References study for a test or final exam?
    - Find someone to study with/set up a study group?
- Organize your files for classes?

References

Ahuja, J. S., & Webster, J. (2001). Perceived disorientation: an examination of a new measure to assess web design effectiveness. *Interacting with Computers, 14*(1), 14 - 29.

Aizawa, K., Tancharoen, D., Kawasaki, S., & Yamasaki, T. (2004). Efficient retrieval of life log based on context and content. In *Proceedings of the 1st ACM workshop on Continuous archival and retrieval of personal experiences* (pp. 22-31). New York, New York, USA: ACM Press.

Allen, D. (2001). *Getting things done: The art of stress-free productivity*. New York: Penguin.

Anderson, R. J. (1994). Representations and requirements: the value of ethnography in system design. *Human-Computer Interaction, 9*, 151 - 182.

Azevedo, R. (2005). Computer Environments as Metacognitive Tools for Enhancing Learning. *Educational Psychologist, 40*(4), 193-197.

Baecker, R. M., Wolf, P., & Rankin, K. (2004). The ePresence Interactive Webcasting System: Technology Overview and Current Research Issues. In *Proceedings of E-Learn 2004* (pp. 2432-2437). Washington, DC.

Barab, S. A., Thomas, M., Dodge, T., Squire, K., & Newell, M. (2004). Critical Design Ethnography: Designing For Change. *Anthropology and Education Quarterly, 35*(2), 254 - 268.

Bardram, J., Bunde-Pedersen, J., & Soegaard, M. (2006). Support for activity-based computing in a personal computing operating system. In *Proceedings of the SIGCHI conference on Human Factors in computing systems* (pp. 211-220). Montreal, Quebec, Canada: ACM Press.

Barkhuus, L., & Dourish, P. (2004). Everyday Encounters with Context-Aware Computing in a Campus Environment. In *Proceedings of the Sixth International Conference on Ubiquitous Computing (UbiComp 2004)* (pp. 232 - 249). Nottingham, England.

Barreau, D. K. (1995). Context as a factor in personal information management systems. *Journal of the American Society for Information Science, 46*(5), 327-339.

Barreau, D. K., Crystal, A., Greenberg, J., Sharma, A., Conway, M., Oberlin, J., et al. (2006). Augmenting memory for student learning: Designing a context-aware capture system for biology education. Poster presented at ASIS&T annual meeting, Austin, TX, November 3 - 8.

Barreau, D. K., & Nardi, B. A. (1995). Finding and reminding: file organization from the desktop. *SIGCHI Bulletin, 27*(3), 39-43.

Barry, C. L. (1994). User-defined relevance criteria: an exploratory study. *Journal of the American Society for Information Science, 45*, 149 - 159.

Bellotti, V., Dalal, B., Good, N., Flynn, P., Bobrow, D. G., & Ducheneaut, N. (2004). What a to-do: studies of task management towards the design of a personal task list manager. In *Proceedings of the SIGCHI conference on Human factors in computing systems* (pp. 735 - 742). Vienna, Austria: ACM Press.

Bellotti, V., Ducheneaut, N., Howard, M., & Smith, I. (2003). Taking email to task: the design and evaluation of a task management centered email tool. In *Proceedings of the SIGCHI conference on Human factors in computing systems* (pp. 345-352). Ft. Lauderdale, Florida, USA: ACM Press.

Bellotti, V., Ducheneaut, N., Howard, M. A., Smith, I. E., & Grinter, R. E. (2005). Quality versus quantity: e-mail-centric task management and its relation with overload. *Human-Computer Interaction, 20*(1-2), 89 - 138.

Bergman, O., Beyth-Marom, R., & Nachmias, R. (2003). The user-subjective approach to personal information management systems. *Journal of the American Society for Information Science and Technology, 54*(9), 872-878.

Bergman, O., Beyth-Marom, R., & Nachmias, R. (2006). The project fragmentation problem in personal information management. In *Proceedings of the SIGCHI conference on Human Factors in computing systems* (pp. 271-274). Montreal, Quebec, Canada: ACM Press.

Beyer, H., & Holtzblatt, K. (1999). Contextual design. *interactions, 6*(1), 32 - 42.

Bisantz, A. M., & Drury, C. G. (2005). Applications of archival and observational data. In J. R. Wilson & N. Corlett (Eds.), *Evaluation of Human Work* (3rd ed., pp. 61 - 83). Boca Raton, FL: CRC Press.

Boardman, R. (2004). *Improving Tool Support for Personal Information Management*. Unpublished dissertation, Imperial College, London.

Boardman, R., & Sasse, M. A. (2004). "Stuff goes into the computer and doesn't come out": a cross-tool study of personal information management. In *Proceedings of the SIGCHI conference on Human factors in computing systems* (pp. 583-590). Vienna, Austria: ACM Press.

Bondarenko, O., & Janssen, R. (2005). Documents at Hand: Learning from Paper to Improve Digital Technologies. In *Proceedings of the SIGCHI conference on Human factors in computing systems* (pp. 121-130). Portland, Oregon, USA: ACM Press.

Borlund, P. (2003). The concept of relevance in IR. *Journal of the American Society for Information Science and Technology, 54*(10), 913 - 925.

Bowker, G., & Star, S. L. (1991). Situations vs. standards in long-term, wide-scale decision-making: the case of the International Classification of Diseases. In *Proceedings of the Twenty-Fourth Annual Hawaii International Conference on System Sciences* (Vol. iv, pp. 73 - 81).

Bradley, N. A., & Dunlop, M. D. (2005). Towards a Multidisciplinary Model of Context to Support Context-Aware Computing. *Human-Computer Interaction, 20*(4), 403 - 446.

Brandt, J., Weiss, N., & Klemmer, S. R. (2007). txt 4 l8r: lowering the burden for diary studies under mobile conditions. In *CHI '07 extended abstracts on Human factors in computing systems* (pp. 2303 - 2308).

Brinck, T., Gergle, D., & Wood, S. D. (2002). *Usability for the Web: Designing Web sites that work*. San Francisco: Morgan Kauffman.

Brotherton, J. A., & Abowd, G. D. (2004). Lessons learned from eClass: Assessing automated capture and access in the classroom. *ACM Transactions on Computer-Human Interaction, 11*(2), 121-155.

Brown, J. S., & Duguid, P. (2000). *The Social Life of Information*. Cambridge, MA: Harvard Business School Press.

Bruce, H. (1998). User satisfaction with information seeking on the Internet. *Journal of the American Society for Information Science, 49*(6), 541-556.

Bruce, H., Jones, W., & Dumais, S. (2004). Information behaviour that keeps found things found. *Information Research, 10*(1).

Buckland, M. K. (1992). Emanuel Goldberg, electronic document retrieval, and Vannevar Bush's Memex. *Journal of the American Society for Information Science, 43*(4), 284-294.

Bulterman, D. C. A. (2004). Is It Time for a Moratorium on Metadata? *IEEE Multimedia, 11*(4), 10 - 17

Bush, V. (1945, July). As we may think. *Atlantic Monthly,* http://www.theatlantic.com/doc/194507/bush.

Button, G. (2000). The ethnographic tradition and design. *Design Studies, 21*(4), 319 - 332.

Capra, R. G. (2006). *An Investigation of Finding and Refinding Information on the Web*. . Unpublished Doctoral dissertation, Virginia Polytechnic Institute and State University, Blacksburg, VA.

Capra, R. G., & Pérez-Quiñones, M. A. (2005). Using Web Search Engines to Find and Refind Information. *IEEE Computer, 38,* 36 - 42.

Carroll, J. M. (2000). Five reasons for scenario-based design. *Interacting with Computers, 13*(1), 43 - 60.

Carter, S., & Mankoff, J. (2005). When participants do the capturing: the role of media in diary studies. In *Proceedings of the SIGCHI conference on Human factors in computing systems* (pp. 899-908). Portland, Oregon, USA: ACM Press.

Chalmers, M. (2004). A Historical View of Context. *Computer-Supported Cooperative Work, 13*(3-4), 223-247.

Chang, M., Leggett, J. J., Furuta, R., Kerne, A., Williams, J. P., Burns, S. A., et al. (2004). Collection understanding. In *Proceedings of the 4th ACM/IEEE-CS joint conference on Digital libraries* (pp. 334-342). Tuscon, AZ, USA: ACM Press.

Cheatle, P. (2004). Media Content and Type Selection from Always-on Wearable Video. In *Proceedings of the 17th International Conference on Pattern Recognition (ICPR'04)* (Vol. 04, pp. 979 - 982).

Chen, Y.-N., & Chen, S.-J. (2005). *Metadata Lifecycle Model and Metadata Interoperability*. Paper presented at the CoLIS Fifth International Conference on Conception of Library and Information Science. Retrieved November 21, 2006, from http://www.sinica.edu.tw/~metadata/bibliography/proceeding/presentation/colis2005.pdf.

Cherry, S. (2005). Totall recall. *IEEE Spectrum, 42*(11), 24 - 30.

Chi, E. (2003). Scent of the web. In J. Ratner (Ed.), *Human factors for web development* (2nd ed., pp. 265-285). Hillsdale, New Jersey.

Chirita, P. A., Gavriloaie, R., Ghita, S., Nejdl, W., & Paiu, R. (2005). Activity Based Metadata for Semantic Desktop Search. In *Lecture Notes in Computer Science : The Semantic Web: Research and Applications* (pp. 439-454).

CIBER. (2008). *Information Behaviour of the Researcher of the Future*. London, UK.

Courage, C., & Baxter, K. (2005). *Understanding your users: A practical guide to user requirements*. San Francisco: Morgan Kaufmann.

Cox, R. (2001). *Managing Records as Evidence and Information*. Westport, CT: Quorum Books.

Crabtree, A., Benford, S., Greenhalgh, C., Tennent, P., Chalmers, M., & Brown, B. (2006). Supporting ethnographic studies of ubiquitous computing in the wild. In *Proceedings of the 6th ACM conference on Designing Interactive systems* (pp. 60-69). University Park, PA, USA: ACM Press.

Crabtree, A., Nichols, D. M., O'Brien, J., Rouncefield, M., & Twidale, M. B. (2000). Ethnomethodologically-informed ethnography and information systems design. *Journal of the Ameican Society for Information Science, 51*(7), 666 - 682.

Crystal, A. (2003). Interface design for metadata creation. In G. Cockton & P. Korhonen (Eds.), *CHI '03 extended abstracts on human factors in computing systems* (pp. 1038 - 1039). Fort Lauderdale, FL.

Crystal, A. (2007). Facets are fundamental: Rethinking information architecture frameworks. *Technical Communication* (February 2007, in press).

Crystal, A., & Greenberg, J. (2006). Relevance criteria identified by health information users during Web searches. *Journal of the American Society for Information Science and Technology, 57*(10), 1368 - 1382.

Cunningham, S. J., & Jones, M. (2005). Autoethnography: a tool for practice and education. In *Proceedings of the 6th ACM SIGCHI New Zealand chapter's international conference on Computer-human interaction: making CHI natural* (pp. 1 - 8). Auckland, New Zealand: ACM Press.

Cuthbert, A., Kubinec, M., Tanis, D. O., Leong, F., Wei, L., & Schlossberg, D. (2005). Advanced technology for streamlining the creation of ePortfolio resources and dynamically-indexing digital library assets: a case study from the digital chemistry project. In *CHI '05 extended abstracts on Human factors in computing systems* (pp. 972-987). Portland, OR, USA: ACM Press.

Cutrell, E., Dumais, S. T., & Teevan, J. (2006). Searching to eliminate personal information management. *Communications of the ACM, 49*(1), 58-64.

Cutrell, E., Robbins, D., Dumais, S., & Sarin, R. (2006). Fast, flexible filtering with phlat. In *Proceedings of the SIGCHI conference on Human Factors in computing systems* (pp. 261-270). Montreal, Quebec, Canada: ACM Press.

Czerwinski, M., Gage, D. W., Gemmell, J., Marshall, C. C., Pérez-Quiñones, M. A., Skeels, M. M., et al. (2006). Digital memories in an era of ubiquitous computing and abundant storage. *Communications of the ACM, 49*(1), 44-50.

Czerwinski, M., Horvitz, E., & Wilhite, S. (2004). A diary study of task switching and interruptions. In *Proceedings of the SIGCHI conference on Human factors in computing systems* (pp. 175-182). Vienna, Austria: ACM Press.

Daniel, G., & Jorge, J. A. (2006). Quill: a narrative-based interface for personal document retrieval. In *CHI '06 extended abstracts on Human factors in computing systems* (pp. 327-332). Montreal, Quebec, Canada: ACM Press.

Davies, S., Allen, S., Raphaelson, J., Meng, E., Engleman, J., King, R., et al. (2006). Popcorn: the personal knowledge base. In *Proceedings of the 6th ACM conference on Designing Interactive systems* (pp. 150-159). University Park, PA, USA: ACM Press.

Davis, M., House, N. V., Towle, J., King, S., Ahern, S., Burgener, C., et al. (2005). MMM2: mobile media metadata for media sharing. In *CHI '05 extended abstracts on Human factors in computing systems* (pp. 1335-1338). Portland, OR, USA: ACM Press.

Dey, A. K., Abowd, G. D., & Salber, D. (2001). A Conceptual Framework and a Toolkit for Supporting the Rapid Prototyping of Context-Aware Applications. *16*(2, 3 & 4), 97-166.

Dong, X., & Halevy, A. (2005). *A Platform for Personal Information Management and Integration*. Paper presented at the Conference on Innovative Data Systems Research (CIDR'05), Asilomar, CA.

Dourish, P. (2000). *Technical and social features of categorisation schemes*.Unpublished manuscript.

Dourish, P. (2001). *Where the action is : the foundations of embodied interaction*. Cambridge, Mass.: MIT Press.

Dourish, P. (2004). What we talk about when we talk about context. *Personal and Ubiquitous Computing, 8*(1), 19.

Dourish, P. (2006). Implications for design. In *Proceedings of the SIGCHI conference on Human Factors in computing systems* (pp. 541-550). Montreal, Quebec, Canada: ACM Press.

Dragunov, A. N., Dietterich, T. G., Johnsrude, K., McLaughlin, M., Li, L., & Herlocker, J. L. (2005). TaskTracer: a desktop environment to support multi-tasking knowledge workers. In *Proceedings of the 10th international conference on Intelligent user interfaces* (pp. 75-82). San Diego, California, USA: ACM Press.

Dray, S., Siegel, D., Feldman, E., & Potenza, M. (2002). "Why do Version 1.0 and not release it?" Conducting Field Trials of the Tablet PC. *interactions, 9*(2), 11 - 16.

Drucker, P. (2002). *The Effective Executive*. New York: Collins.

Dumais, S., Cutrell, E., Cadiz, J. J., Jancke, G., Sarin, R., & Robbins, D. C. (2003). Stuff I've seen: a system for personal information retrieval and re-use. In *Proceedings of the 26th annual international ACM SIGIR conference on Research and development in informaion retrieval* (pp. 72-79). Toronto, Canada: ACM Press.

Duyne, D. K. V., Landay, J. A., & Hong, J. I. (2003). *The Design of Sites: Patterns, Principles, and Processes for Crafting a Customer-Centered Web Experience*. Boston: Pearson.

Dziadosz, S., & Chandrasekar, R. (2002). Do thumbnail previews help users make better relevance decisions about Web search results? In *Proceedings of the 25th Annual International ACM SIGIR Conference on Research and Development in Information Retrieval, August 11-15, 2002, Tampere, Finland* (pp. 365 - 366): ACM Press.

Efron, M., Elsas, J., Marchionini, G., & Zhang, J. (2004). Machine learning for information architecture in a large governmental website. In *Proceedings of the 4th ACM/IEEE-CS joint conference on Digital libraries* (pp. 151-159). Tuscon, AZ, USA: ACM Press.

Elliott, M. A. (2007). *Stigmergic Collaboration: A Theoretical Framework for Mass Collaboration*. Unpublished Ph.D. dissertation, University of Melbourne.

Ericsson, K. A. (2007). Deliberate practice and the modifiability of body and mind: Toward a science of the structure and acquisition of expert and elite performance. *International Journal of Sport Psychology, 38*, 4-34.

Eveland, J., William P. , & Dunwoody, S. (2001). User control and structural isomorphism or disorientation and cognitive load? *Communication Research, 28*(1), 48 - 78.

Fakas, G., Nguyen, A., & Gillet, D. (2005). The Electronic Laboratory Journal: A Collaborative and Cooperative Learning Environment for Web-Based Experimentation. *Computer Supported Cooperative Work (CSCW), 14*(3), 216.

FAO. (2006). Food And Agriculture Organization Of The United Nations: Metadata Schemas. Retrieved November 13, 2006, from http://www.fao.org/aims/meta_ns.jsp

Fast, K. V., & Campbell, D. G. (2004). "I still like Google": University Student Perceptions of Searching OPACs and the Web. In *Proceedings of the ASIST 2004 Annual Meeting: "Managing and Enhancing Information: Cultures and Conflicts" (ASIST AM 04)*. Providence, Rhode Island, November 13 - 18, 2004.

Fleck, R. (2003, November 26 - 28). *Supporting reflection and learning with new technology*. Paper presented at the OZCHI Doctoral Consortium, Brisbane, Australia. Retrieved from: http://www.cogs.susx.ac.uk/users/rmmf20/OZCHI%20Rowanne%20Fleck%20copy.pdf.

Fleck, R. (2006). Exploring SenseCam to inform the design of image capture and replay devices for supporting reflection. from http://hct.fcs.sussex.ac.uk/Submissions/06.pdf

Frew, J., Freeston, M., Kemp, R. B., Simpson, J., Smith, T., Wells, A., et al. (1996). The Alexandria Digital Library Testbed. *D-Lib Magazine,* July/August.

Gaver, B., Dunne, T., & Pacenti, E. (1999). Design: Cultural probes. *interactions, 6*(1), 21-29.

Gemmell, J. (2006). Reflections from Jim Gemmell at Microsoft Research. Retrieved October 30, 2006, from http://aster.its.unc.edu/blog/?p=87.

Gemmell, J., Bell, G., & Lueder, R. (2006). MyLifeBits: a personal database for everything. *Communications of the ACM, 49*(1), 88-95.

Gemmell, J., Williams, L., Wood, K., Lueder, R., & Bell, G. (2004). Passive capture and ensuing issues for a personal lifetime store. In *Proceedings of the the 1st ACM workshop on Continuous archival and retrieval of personal experiences* (pp. 48-55). New York, New York, USA: ACM Press.

Gibbons, S. (2007). *The academic library and the net gen student: making the connections*. Chicago, IL: American Library Association.

Gibbons, S., & Foster, N. F. (2007). Conclusion: Creating Student-Centered Academic Libraries. In *Studying Students: The Undergraduate Reseach Project at the University of Rochester* (pp. 79 - 83). Chicago: Association of College and Research Libraries.

Gilliland-Swetland, A. J. (2000). *Enduring Paradigm, New Opportunities: The Value of the Archival Perspective in the Digital Environment*. Washington, D.C.: Council on Library and Information Resources.

Glesne, C. (2005). *Becoming Qualitative Researchers: An Introduction* (2nd ed.). Boston, MA: Allyn & Bacon.

Gosling, S. D., Ko, S. J., Mannarelli, T., & Morris, M. E. (2002). A Room with a cue: Judgments of personality based on offices and bedrooms. *Journal of Personality and Social Psychology*(82), 379-398.

Green, A., & Kent, J.-P. (2002). *The Metadata Life Cycle* (in MetaNet Work Package 1: Methodology and Tools No. IST-1999-29093): pp. 29 - 34. Retrieved from http://www.epros.ed.ac.uk/metanet/deliverables/D4/IST_1999_29093_D4.pdf .

Greenberg, J., Crystal, A., Robertson, W. D., & Leadem, E. (2003). Iterative design of metadata creation tools for resource authors. In *Proceedings of the 2003 Dublin Core Conference: Supporting Communities of Discourse and Practice—Metadata Research and Applications*. Seattle, WA.

Greenberg, J., Crystal, A., Sharma, A., Mendez, E., Oberlin, J., & Shoffner, M. (2006). Memex Metadata (M2) for Reflective Learning. In *Proceedings of the*

2006 Dublin Core Conference: Metadata for Knowledge and Learning. Manzanillo, Mexico, October 3 - 6.

Greenberg, J., Spurgin, K., & Crystal, A. (2006). Functionalities for automatic metadata generation applications: a survey of metadata experts' opinions. *International Journal of Metadata, Semantics & Ontologies, 1*(1).

Guven, S., Podlaseck, M., & Pingali, G. (2005). PICASSO: Pervasive Information Chronicling, Access, Search, and Sharing for Organizations. In *Third IEEE International Conference on Pervasive Computing and Communications (PerCom'05)* (pp. 341 - 350).

Hacker, D. J. (1998). Metacognition: Definitions and empirical foundations. In D. J. Hacker, J. Dunlosky & A. C. Graesser (Eds.), *Metacognition in Educational Theory and Practice* (pp. 1 - 23). Mahwah, NJ: Lawrence Erlbaum Associates.

Hacker, D. J., Dunlosky, J., & Graesser, A. C. (Eds.). (1998). *Metacognition in Educational Theory and Practice*. Mahwah, NJ: Lawrence Erlbaum Associates.

Hallnäs, L., & Redström, J. (2002). From use to presence: on the expressions and aesthetics of everyday computational things. *ACM Transactions on Computer-Human Interaction, 9*(2), 106 - 124.

Halverson, C., Erickson, T., & Ackerman, M. (2004). Behind the help desk: evolution of a knowledge management system in a large organization. *Proceedings of the ACM conference on Computer supported cooperative work (CSCW '04)* (Chicago, IL, November 6 – 10), 304 - 313.

Hammond, T., Hannay, T., Lund, B., & Scott, J. (2005). Social Bookmarking Tools (I): A General Review. *D-Lib Magazine, 11*(4).

Head, A. J. (2007). Beyond Google: How do students conduct academic research? *First Monday, 12*(8).

Henderson, S. (2005). Genre, task, topic and time: facets of personal digital document management. In *Proceedings of the 6th ACM SIGCHI New Zealand chapter's international conference on Computer-human interaction: making CHI natural* (pp. 75-82). Auckland, New Zealand: ACM Press.

Hershkowitz, R., & Schwartz, B. B. (1999). Reflective Processes in a Mathematics Classroom With a Rich Learning Environment. *Cognition and Instruction, 17*(1), 65-92.

Heylighen, F., & Vidal, C. (2007). Getting Things Done: the Science behind Stress-Free Productivity. Retrieved March 17, 2008, from http://pespmc1.vub.ac.be/Papers/GTD-cognition.pdf

Hignett, S. (2005). Qualitative Methodology. In J. R. Wilson & N. Corlett (Eds.), *Evaluation of Human Work* (3rd ed., pp. 113 - 129). Boca Raton, FL: CRC Press.

Hinrichs, J., Pipek, V., & Wulf, V. (2005). Context grabbing: Assigning metadata in large document collections. In *Proceedings of the 9th European Conference on Computer-Supported Cooperative Work (ECSCW'05)* (pp. 267 - 287). Paris, France: Springer.

Hori, T., & Aizawa, K. (2003). Context-based video retrieval system for the life-log applications. In *Proceedings of the 5th ACM SIGMM international workshop on Multimedia information retrieval* (pp. 31-38). Berkeley, California: ACM Press.

Horwath, J., & Williamson, C. (2008). *The kids are alright – or are they?* Paper presented at the WILU 38: Information Literacy Uncorked. from http://eprints.rclis.org/archive/00013639/01/kids_are_alright_Horwath_Williamson.pdf.

Hufford, J. (1991). Elements of the Bibliographic Record Used by Reference Staff Members. *College & Research Libraries, 52*(1), 54-64.

Hurst, M. (2007). *Bit Literacy: Productivity in the Age of Information and E-mail Overload* New York: Good Experience Press.

Hutchinson, H., Mackay, W., Westerlund, B., Bederson, B. B., Druin, A., Plaisant, C., et al. (2003). Technology probes: inspiring design for and with families. In *Proceedings of the SIGCHI conference on Human factors in computing systems* (pp. 17-24). Ft. Lauderdale, Florida, USA: ACM Press.

Ireland, C. (2003). Qualitative methods: from boring to brilliant. In B. Laurel (Ed.), *Design Research* (pp. 23 - 29). Cambridge, MA: MIT Press.

Ishii, N., & Miwa, K. (2005). Supporting reflective practice in creativity education. In *Proceedings of the 5th conference on Creativity & cognition* (pp. 150-157). London, United Kingdom: ACM Press.

Jacob, E. (2001). The everyday world of work: two approaches to the investigation of classification in context *Journal of Documentation, 57*(1), 76 - 99.

Jo, lle, B., Stefan, A., & Matthew, K. (2004). RAW: conveying minimally-mediated impressions of everyday life with an audio-photographic tool. In *Proceedings of the SIGCHI conference on Human factors in computing systems* (pp. 495-502). Vienna, Austria: ACM Press.

Johnson, J., & Kniesner, D. (2003). Moving Image Collections glossary. Retrieved November 13, 2006, from http://gondolin.rutgers.edu/MIC/text/how/Catalog_info.htm

Johnson, J. D. (2003). On contexts of information seeking. *Information Processing & Management, 39*(5), 735.

Jones, W. (2004). Finders, keepers? The present and future perfect in support of personal information management. *First Monday, 9*(3).

Jones, W. (2007). Personal Information Management. In B. Cronin (Ed.), *Annual Review of Information Science and Technology* (Vol. 41, pp. 453-504). Medford, NJ: Information Today.

Jones, W., & Bruce, H. (2005). *A Report on the NSF-Sponsored Workshop on Personal Information Management*. Seattle, WA: Retrieved from http://pim.ischool.washington.edu/.

Jones, W., Munat, C. F., Bruce, H., & Foxley, A. (2005). *The Universal Labeler: Plan the Project and Let Your Information Follow*. Paper presented at the 68th Annual Meeting of the American Society for Information Science and Technology, Charlotte, NC.

Jones, W., Phuwanartnurak, A. J., Gill, R., & Bruce, H. (2005). Don't take my folders away!: organizing personal information to get things done. In *CHI '05 extended abstracts on Human factors in computing systems*. Portland, OR, USA: ACM Press.

Kaptelinin, V. (2003). UMEA: translating interaction histories into project contexts. In *Proceedings of the SIGCHI conference on Human factors in computing systems* (pp. 353-360). Ft. Lauderdale, Florida, USA: ACM Press.

Karger, D. R., Bakshi, K., Huynh, D., Quan, D., & Sinha, V. (2003). Haystack: A Customizable General-Purpose Information Management Tool for End Users of Semistructured Data. In *Proceedings of the 2003 CIDR Conference*. Retrieved from http://www-db.cs.wisc.edu/cidr/cidr2005/papers/P02.pdf.

Karger, D. R., & Quan, D. (2004). Collections: flexible, essential tools for information management. In *CHI '04 extended abstracts on Human factors in computing systems* (pp. 1159-1162). Vienna, Austria: ACM Press.

Kerne, A., Smith, S. M., Choi, H., Graeber, R., & Caruso, D. (2005). Evaluating navigational surrogate formats with divergent browsing tasks. In *CHI '05 extended abstracts on Human factors in computing systems* (pp. 1537 - 1540). Portland, OR, USA: ACM Press.

Kirsh, D. (2001). The context of work. *Human-Computer Interaction, 16*, 305 - 322.

Kirsh, D. (2005). Metacognition, Distributed Cognition and Visual Design. In P. G. P. Johansson (Ed.), *Cognition, Education and Communication Technology*: Lawrence Erlbaum.

Kolb, D. A. (1984). *Experiential Learning*. Englewood Cliffs, NJ.: Prentice Hall.

Komlodi, A., Marchionini, G., & Soergel, D. (2007). Search history support for finding and using information: User interface design recommendations from a user study. *Information Processing & Management, 43*(1), 10 - 29.

Krishnan, A., & Jones, S. (2005). TimeSpace: activity-based temporal visualisation of personal information spaces. *Personal and Ubiquitous Computing, V9*(1), 46.

Kwasnik, B. (1989). How a personal document's intended use or purpose affects its classification in an office. In *Proceedings of the 12th annual international ACM SIGIR conference on Research and development in information retrieval* (pp. 207 - 210). Cambridge, Massachusetts, United States: ACM Press.

Kwasnik, B. (1999). The role of classification in knowledge representation and discovery. *Library Trends, 48*(1), 22 - 47.

Lan, W.-C. (2002). *From document clues to descriptive metadata*. Unpublished Dissertation, University of North Carolina at Chapel Hill, Chapel Hill, NC.

Landry, B. M., & Guzdial, M. (2006). iTell: supporting retrospective storytelling with digital photos. In *Proceedings of the 6th ACM conference on Designing Interactive systems* (pp. 160-168). University Park, PA, USA: ACM Press.

Lansdale, M. W. (1988). The psychology of personal information management. *Applied Ergonomics, 19*(1), 55.

Levy, D. M. (1995). Cataloging in the digital order. In *Proceedings of the Second Annual Conference on the Theory and Practice of Digital Libraries*. Austin, TX: ACM Press.

Levy, D. M. (2005). To grow in wisdom: Vannevar Bush, information overload, and the life of leisure. In *Proceedings of the 5th ACM/IEEE-CS joint conference on Digital libraries* (pp. 281-286). Denver, CO, USA: ACM Press.

Liddy, E. (2002, November 18 - 21). Automatic Metadata Generation & Evaluation. *ASIST 2002* Retrieved December 2nd, 2003, from http://cnlp.org/presentations/slides/MetaData.ASIST.2002.ppt

Liu, P., Yang, S., & Vemuri, S. (2005). Beyond Human Memory: Memex in Personal Information Management. Retrieved November 13, 2006, from http://pubs.dlib.vt.edu:9090/42/01/SenseCamFinalReport.pdf

Looker, E. D., & Thiessen, V. (2003). Beyond the digital divide in Canadian schools - From access to competency in the use of information technology. *Social Science Computer Review, 21*(4), 475-490.

Luchini, K., Quintana, C., & Soloway, E. (2004). Design guidelines for learner-centered handheld tools. In *Proceedings of the SIGCHI conference on Human factors in computing systems* (pp. 135-142). Vienna, Austria: ACM Press.

Luescher, M. (2004). *Microsoft's Lookout Search Tool*: Retrieved from http://www.ferris.com/view_content.php?o=Email&id=704.

Madelene, L., Anna, S., hl, Kristina, H., Petra, S., Jarmo, L., et al. (2006). Affective diary: designing for bodily expressiveness and self-reflection. In *CHI '06 extended abstracts on Human factors in computing systems* (pp. 1037-1042). Montreal, Quebec, Canada: ACM Press.

Mainwaring, S. D., Chang, M. F., Anderson, K., Davies, N., Mynatt, E., & Siio, I. (2004). Infrastructures and their discontents: Implications for ubicomp. In *Proceedings of the Sixth International Conference on Ubiquitous Computing (UbiComp 2004)* (pp. 418-432). Nottingham, England.

Malone, T. W. (1983). How do people organize their desks? Implications for the design of office information systems. *ACM Transactions on Office Information Systems, 1*(1), 99 - 112.

Mangiafico, P. (2007). *Playing with information*. Paper presented at the LAUNC-CH Conference. Retrieved 10/6/07, from http://www.duke.edu/%7Epaulm/slides/Mangiafico-LAUNC-CH-12March2007.pdf.

Mann, S. (2004). Continuous lifelong capture of personal experience with EyeTap. In *Proceedings of the the 1st ACM workshop on Continuous archival and retrieval of personal experiences* (pp. 1-21). New York, New York, USA: ACM Press.

Mann, S., & Fung, J. (2002). EyeTap devices for augmented, deliberately diminished, or otherwise altered visual perception of rigid planar patches of real-world scenes. *Presence: Teleopererators and Virtual Environments, 11*(2), 158-175.

Marchionini, G. (1995). *Information seeking in electronic environments*. Cambridge ; New York: Cambridge University Press.

Marchionini, G. (2006). Exploratory search: from finding to understanding. *Communications of the ACM, 49*(4), 41-46.

Marchionini, G., Geisler, G., & Brunk, B. (2000, November 15 - 18, 2000). *Agileviews: A Human-Centered Framework for Interfaces to Information Spaces*. Paper presented at the ASIS 2000 Annual Meeting, Chicago, IL.

Marchionini, G., Wildemuth, B. M., & Geisler, G. (2006). The Open Video Digital Library: A Möbius strip of research and practice. *Journal of the American Society for Information Science and Technology, 57*(12), 1629-1643.

Marshall, C. C. (1998). Making metadata: a study of metadata creation for a mixed physical-digital collection. In I. Witten, R. Akscyn & I. Frank M. Shipman (Eds.), *Proceedings of the third ACM conference on digital libraries* (pp. 162 - 171). Pittsburgh, PA.

Maxwell, J. A. (2005). *Qualitative Research Design: An Interactive Approach* (2nd ed.). Thousand Oaks, CA: Sage.

McAdams, D. P. (2001). The psychology of life stories. *Review of General Psychology, 5*(2), 100-122.

McClelland, I., & Suri, J. F. (2005). Involving people in design. In J. R. Wilson & N. Corlett (Eds.), *Evaluation of Human Work* (3rd ed., pp. 281 - 335). Boca Raton, FL: CRC Press.

Mehl, M. R. (2007). Eavesdropping on health: A naturalistic observation approach for social-health research. *Social and Personality Psychology Compass, 1,* 359-380.

Mehl, M. R., Pennebaker, J. W., Crow, M. D., Dabbs, J., & Price, J. H. (2001). The Electronically Activated Recorder (EAR): A device for sampling naturalistic daily activities and conversations. *Behavior Research Methods, Instruments, and Computers, 33,* 517-523.

Merriam, S. B. (1998a). Mining data from documents. In *Qualitative research and case study applications in education* (pp. 112 - 134). San Francisco: Jossey-Bass.

Merriam, S. B. (1998b). *Qualitative research and case study applications in education*. San Francisco: Jossey-Bass.

Mick, D. G., & Fournier, S. (1998). Paradoxes of Technology: Consumer Cognizance, Emotions, and Coping Strategies. *Journal of Consumer Research, 25*(2), 123 - 143.

Millen, D. R. (2000). Rapid ethnography: time deepening strategies for HCI field research. In *Proceedings of the conference on Designing interactive systems: processes, practices, methods, and techniques* (pp. 280-286). New York City, New York, United States: ACM Press.

Miller, E. (2002). The Semantic Web. In E. G. Toms (Ed.), *Proceedings of the 65th ASIST Annual Meeting* (pp. 495 - 496). Philadelphia, PA.

Mizzaro, S. (1997). Relevance: the whole history. *Journal of the American Society for Information Science, 48*(9), 810 - 832.

Moon, J. A. (1999). *Reflection in learning and professional development*. London: Kogan Page Limited.

Moran, T. P., Palen, L., Harrison, S., Chiu, P., Kimber, D., Minneman, S., et al. (1997). "I'll get that off the audio": a case study of salvaging multimedia meeting records. In *Proceedings of the SIGCHI conference on Human factors in computing systems* (pp. 202-209). Atlanta, Georgia, United States: ACM Press.

Morgenstern, J. (2004). *Organizing from the Inside Out* (2nd ed.). New York: Owl Books.

Naaman, M., Harada, S., Wang, Q., Garcia-Molina, H., & Paepcke, A. (2004). Context data in geo-referenced digital photo collections. In *Proceedings of the 12th annual ACM international conference on Multimedia* (pp. 196-203). New York, NY, USA: ACM Press.

Naaman, M., Song, Y. J., Paepcke, A., & Garcia-Molina, H. (2004). Automatic organization for digital photographs with geographic coordinates. In *Proceedings of the 4th ACM/IEEE-CS joint conference on Digital libraries* (pp. 53-62). Tuscon, AZ, USA: ACM Press.

Naaman, M., Yeh, R. B., Garcia-Molina, H., & Paepcke, A. (2005). Leveraging context to resolve identity in photo albums. In *Proceedings of the 5th ACM/IEEE-CS joint conference on Digital libraries* (pp. 178-187). Denver, CO, USA: ACM Press.

Nack, F. (2005). You Must Remember This. *Multimedia, IEEE, 12*(1), 4.

Nejdl, W., & Paiu, R. (2005). *Desktop Search - How Contextual Information Influences Search Results & Rankings*. Paper presented at the ACM SIGIR 2005 Workshop on Information Retrieval in Context (IRiX), Salvador, Brazil.

Neumann, L. J. (1999). Paper, Piles, and Computer Files: Folklore of Information Work Environments *Library Trends, 47*(3), 439 - 469.

Nørgaard, M., & Hornbæk, K. (2006). What do usability evaluators do in practice?: an explorative study of think-aloud testing. In *Proceedings of the 6th ACM conference on Designing Interactive systems* (pp. 209-218). University Park, PA, USA: ACM Press.

Norman, D. A. (2005). Human-centered design considered harmful. *interactions, 12*(4), 14-19.

Norman, D. A. (2006). Why doing user observations first is wrong. *interactions, 13*(4), 50.

Oulasvirta, A. (2004). Finding meaningful uses for context-aware technologies: the humanistic research strategy. In *Proceedings of the SIGCHI conference on Human factors in computing systems* (pp. 247-254). Vienna, Austria: ACM Press.

Papert, S. (1980). *Mindstorms: Children, Computers, and Powerful Ideas*. New York, NY: Basic Books.

Petras, V., Larson, R. R., & Buckland, M. (2006). Time period directories: a metadata infrastructure for placing events in temporal and geographic context. In *Proceedings of the 6th ACM/IEEE-CS joint conference on Digital libraries* (pp. 151-160). Chapel Hill, NC, USA: ACM Press.

Potts, C., & Newstetter, W. C. (1997). Naturalistic inquiry and requirements engineering: reconciling their theoretical foundations. In *Proceedings of the Third IEEE International Symposium on Requirements Engineering (RE'97)* (pp. 118 - 127). Annapolis, MD, USA.

Pressley, M., Van Etten, S., Yokoi, L., Freebern, G., & Van Meter, P. (1998). The metacognition of college studentship: A grounded theory approach. In *Metacognition in Theory and Practice* (pp. 347 - 367). Mahwah, NJ: Lawrence Erlbaum.

Pruitt, J., & Adlin, T. (2006). *The persona lifecycle: Keeping People in Mind Throughout Product Design*. San Francisco, CA: Morgan Kaufmann.

Rasmussen, E. (1997). Indexing images. *Annual Review of Information Science and Technology, 32*, 169 - 196.

Ravasio, P., Schär, S. G., & Krueger, H. (2004). In pursuit of desktop evolution: User problems and practices with modern desktop systems. *ACM Transactions on Computer-Human Interaction, 11*(2), 156-180.

Rhee, Y., Kim, J., & Chung, A. (2006). Your phone automatically caches your life. *interactions, 13*(4), 42-44.

Richter, H., Miller, C., Abowd, G. D., & Hsi, I. (2005). An empirical investigation of capture and access for software requirements activities. In *Proceedings of the 2005 conference on Graphics interface* (pp. 121-128). Victoria, British Columbia: Canadian Human-Computer Communications Society.

Rieh, S. Y. (2002). Judgment of information quality and cognitive authority in the Web. *Journal of the American Society for Information Science and Technology, 53*(2), 145-161.

Ringel, M., Cutrell, E., Dumais, S. T., & Horvitz, E. (2003). Milestones in Time: The Value of Landmarks in Retrieving Information from Personal Stores. In *Proceedings of INTERACT 2003*. Retrieved from: http://research.microsoft.com/~cutrell/SISLandmarks_Interact2003.pdf .

Rogers, Y., Scaife, M., Harris, E., Phelps, T., Price, S., Smith, H., et al. (2002). Things aren't what they seem to be: innovation through technology inspiration. In *Proceedings of the conference on Designing interactive systems: processes, practices, methods, and techniques* (pp. 373 - 378). London, England: ACM Press.

Rosson, M. B., & Carroll, J. M. (2003). Scenario-based design. In J. A. Jacko & A. Sears (Eds.), *The Human-Computer Interaction Handbook: Fundamentals, Evolving Technologies and Emerging Applications* (pp. 1032 - 1050). Mahwah, NJ: Lawrence Erlbaum Associates.

Rothrock, B., Myers, B. A., & Wang, S. H. (2006). Unified associative information storage and retrieval. In *CHI '06 extended abstracts on Human factors in computing systems* (pp. 1271-1276). Montreal, Quebec, Canada: ACM Press.

Rubinstein, R., & Hersh, H. (1984). *The Human Factor: Designing Computer Systems for People*. Burlington, MA: Digital Press. Cited in Pruitt & Adlin (2006), p. 130.

Saracevic, T., Kantor, P., Chamis, A. Y., & Trivison, D. (1988). A Study of Information Seeking and Retrieving .1. Background and Methodology. *Journal of the American Society for Information Science, 39*(3), 161-176.

Sasse, M. A. (1997). *Eliciting and Describing Users' Models of Computer Systems*. University of Birmingham, Birmingham, England.

schraefel, m. c., Smith, D. A., Owens, A., Russell, A., Harris, C., & Wilson, M. (2005). The evolving mSpace platform: leveraging the semantic web on the trail of the memex. In *Proceedings of the sixteenth ACM conference on Hypertext and hypermedia* (pp. 174-183). Salzburg, Austria: ACM Press.

Schraw, G., Crippen, K. J., & Hartley, K. (2006). Promoting Self-Regulation in Science Education: Metacognition as Part of a Broader Perspective on Learning. *Research in Science Education, V36*(1), 111.

Schwartz, H., & Jacob, J. (1979). *Qualitative Sociology: A Method to the Madness*. New York: Free Press.

Sellen, A. J., Murphy, R., & Shaw, K. L. (2002). How knowledge workers use the web. *Proceedings of the ACM SIGCHI Conference on Human factors in computing systems (CHI'02)*, 227 - 234.

Sengers, P., & Gaver, B. (2006). Staying open to interpretation: engaging multiple meanings in design and evaluation. In *Proceedings of the 6th ACM conference on Designing Interactive systems* (pp. 99-108). University Park, PA, USA: ACM Press.

Sinclair, M. A. (2005). Participative assessment. In J. R. Wilson & N. Corlett (Eds.), *Evaluation of Human Work* (3rd ed., pp. 83 - 113). Boca Raton, FL: CRC Press.

Singh, S., & Bartolo, K. (2005). Grounded Theory and User Requirements: a challenge for qualitative research. *Australasian Journal of Information Systems, 12*(2), 90 - 102.

Smith, G., Boyd, D., Golder, S., Murison, J., Sinha, R., & Yin, M. (2006). Tagging and Beyond: Personal, Social and Collaborative Information Architecture. Panel at the 7th annual ASIS&T Information Architecture Summit, Vancouver, BC (March 23 - 27).

Solomon, K. (2007). Describing what ethnography is good for: Anthrodesign listserv, accessed 4/6/08.

Spinuzzi, C. (2006). What Do We Need to Teach About Knowledge Work? *Computer Writing and Research Lab White Paper Series*, 060925-1, from http://www.cwrl.utexas.edu/node/962

Strauss, A. (1988). The articulation of project work: An organizational process. *The Sociological Quarterly, 29*(2), 163-178.

Susi, T., & Ziemke, T. (2001). Social cognition, artefacts, and stigmergy: A comparative analysis of theoretical frameworks for the understanding of artefact-mediated collaborative activity. *Cognitive Systems Research, 2*(4), 273-290.

Sutherland, R., Armstrong, V., Barnes, S., Brawn, R., Breeze, N., Gall, M., et al. (2004). Transforming teaching and learning: embedding ICT into everyday classroom practices. *Journal of Computer Assisted Learning, 20*, 413 - 425.

Tang, J., Lin, J., Pierce, J., Whittaker, S., & Clemens, D. (2007). Recent shortcuts: using recent interactions to support shared activities. In *Proceedings of the SIGCHI conference on Human factors in computing systems* (pp. 1263-1272). San Jose, California, USA: ACM.

Tang, P., & Solomon, P. (2001). Use of relevance criteria across stages of document evaluation: On the complementarity of experimental and naturalistic studies. *Journal of the American Society for Information Science and Technology, 52*(8), 676-685.

Taylor, A. S., & Swan, L. (2004). List making in the home. In *Proceedings of the 2004 ACM conference on Computer supported cooperative work* (pp. 542-545). Chicago, Illinois, USA: ACM Press.

Taylor, A. S., & Swan, L. (2005). Artful systems in the home. In *Proceedings of the SIGCHI conference on Human factors in computing systems* (pp. 641-650). Portland, Oregon, USA: ACM Press.

Tee, K., Greenberg, S., & Gutwin, C. (2006). Providing artifact awareness to a distributed group through screen sharing. In *Proceedings of the 2006 20th anniversary conference on Computer supported cooperative work* (pp. 99-108). Banff, Alberta, Canada: ACM.

Teevan, J., Alvarado, C., Ackerman, M. S., & Karger, D. R. (2004). The perfect search engine is not enough: a study of orienteering behavior in directed search. In *Proceedings of the SIGCHI conference on Human factors in computing systems* (pp. 415-422). Vienna, Austria: ACM Press.

Tombros, A., Ruthven, I., & Jose, J. M. (2005). How users assess web pages for information seeking. *Journal of the American Society for Information Science and Technology, 56*(4), 327 - 344.

Trigg, R. H., Blomberg, J., & Suchman, L. (1999). Moving document collections online: the evolution of a shared repository. In S. Bødker, M. Kyng & K. Schmidt (Eds.), *Proceedings of the Sixth European Conference on Computer Supported Cooperative Work* (pp. 331 - 350). Copenhagen, Denmark: Kluwer Academic Publishers.

Veltkamp, R. C., & Tanase, M. (2002). *Content-Based Image Retrieval Systems: A Survey* (No. UU-CS-2000-34): Department of Computing Science, Utrecht University. Retrieved from: http://www.aa-lab.cs.uu.nl/cbirsurvey/cbir-survey/.

Vemuri, S., Schmandt, C., Bender, W., Tellex, S., & Lassey, B. (2004). An Audio-Based Personal Memory Aid. In *Proceedings of the Sixth International Conference on Ubiquitous Computing (UbiComp 2004)*. Nottingham, England.

Wang, Y., Wang, W., Luo, Y., Wang, X., & Xu, Z. (2004). A Metadata Framework for Distributed Geo-spatial Databases in Grid Environment. In *Proceedings of* *the Conference on Grid and Cooperative Computing (GCC 2004)* (pp. 153-160).

Whang, Z., & Gemmell, J. (2006). *Clean Living: Eliminating Near-Duplicates in Lifetime Personal Storage* (No. MSR-TR-2006-30).

Whittaker, S., Terveen, L., & Nardi, B. A. (2000). Let's Stop Pushing the Envelope and Start Addressing It: A Reference Task Agenda for HCI. *Human-Computer Interaction, 15*(2&3), 75-106.

Wilkens-Adessa, T. (2006). A new framework. Retrieved 10/17/06, from http://www.adaptivepath.com/blog/2006/07/13/a-new-framework/

Williamson, A. (1998). Moneypenny: lessons from the messy desk. *Interacting with Computers, 9*(3), 241.

Woodruff, A., Rosenholtz, R., Morrison, J. B., Faulring, A., & Pirolli, P. (2002). A comparison of the use of text summaries, plain thumbnails, and enhanced thumbnails for Web search tasks. *Journal of the American Society for Information Science and Technology, 53*(2), 172-185.

Yates, J., & Orlikowski, W. (in press). The PowerPoint Presentation and Its Corollaries: How Genres Shape Communicative Action in Organizations. In M. Zachry & C. Thralls (Eds.), *The Cultural Turn: Communicative Practices in Workplaces and the Professions*. Amityville, NY: Baywood Publishing.

Yee, P., Swearingen, K., Li, K., & Hearst, M. (2003). Faceted Metadata for Image Search and Browsing. In *Proceedings of the 2003 conference on Human factors in computing systems (CHI'03)*. Fort Lauderdale, FL: ACM Press.

Yeh, R., Liao, C., Klemmer, S., Guimbretiere, F., Lee, B., Kakaradov, B., et al. (2006). ButterflyNet: a mobile capture and access system for field biology research. In *Proceedings of the SIGCHI conference on Human Factors in computing systems* (pp. 571-580). Montreal, Quebec, Canada: ACM Press.

Yilmazel, O., Finneran, C. M., & Liddy, E. (2004). MetaExtract: An NLP System to Automatically Assign Metadata. *Proceedings of the 4th ACM/IEEE-CS joint conference on Digital libraries (JCDL '04)* (Tuscon, AZ, USA, June 7 - 11), 241 - 242.

Zhang, J., & Marchionini, G. (2005). Evaluation and evolution of a browse and search interface: relation browser. In *Proceedings of the 2005 national conference on Digital government research* (pp. 179 - 188). Atlanta, Georgia: Digital Government Research Center.