Interacting with Heterogeneous Information Ecologies: Challenges and Opportunities for Students in Diverse and Distributed Learning Environments

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ABSTRACT

The rise of heterogeneous information leads to questions of how people find, manage, and use information in increasingly fragmented ecologies. The extent to which interactive technologies can be re-designed to help people thrive in these environments should be explored. A two-phase study is proposed to investigate the effects of heterogeneous information on undergraduates' interactions with their information ecologies. Phase one will examine how students interact with the elements of their information ecologies. Phase two will explore how tools can be re-designed to help students more cohesively weave elements of their information ecologies together. An Activity Theoretical approach to these questions will be taken by examining the relationships between people, information, and tools.

CCS CONCEPTS

• **Information systems** → *Users and interactive retrieval*; *Multimedia and multimodal retrieval*;

KEYWORDS

Activity Theory; Information Ecology; Personal Information Management.

1 MOTIVATION

How do individuals interact with information, tools, and people within their increasingly diverse and distributed information ecologies? While the research literature has shown that the amount of available information can be overwhelming [1, 14] and difficult to manage [18, 41], existing work has primarily focused on text-based information. This emphasis overlooks the heterogeneity of
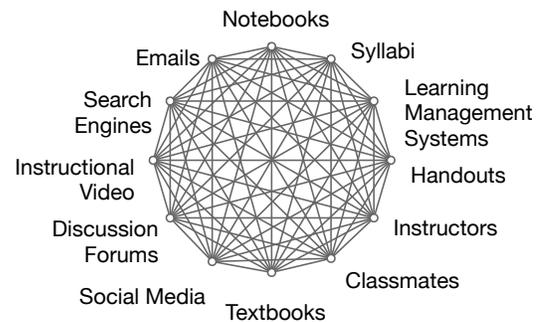
Figure 1: Students' information ecologies are made up of diverse and distributed information, people, and tools. Ecologies are dynamic, and may change through the addition, subtraction, or alteration of elements.

information, and the difficulty people have constructing and sustaining networks of information, people, and tools. For example, information is often divided up by the tools used to create or consume content (e.g., email clients, image viewers, video players, web browsers, word processors, etc.), leading to the breaking up of information ecologies by media type rather than weaving elements together through spatial, semantic, or social relationships [2, 3]. The proposed research will investigate the ways in which information ecologies are both enriched *and* fragmented by diverse and distributed information, people, and tools, and explore the means by which people are adapting their information practices to these challenges.

Students experience breakdowns in their information ecologies that need to be repaired in order for them to engage in learning activities, including, but not limited to, note taking, homework, and preparing for exams [11]. Information ecologies are systems of interdependent elements (e.g., information, people, practices, tools, and values) that support human information interaction [31]. The proposed research will draw this metaphor out further by examining the nature of elements within these information ecologies. The breakdowns in information ecologies caused by heterogeneous information have been under-explored in the research literature. Heterogeneous information refers to distinctions between not only the type of media information is communicated through but also the material and social aspects of information. Breakdowns can prevent individuals from taking control of their learning, and may

lead to a culture of distrust in authoritative and credible sources or a filtering of information that does not conform to beliefs or expectations [32].

Students face challenges when using heterogeneous information on a daily basis as part of their learning activities. The proposed research will investigate how undergraduates interact with their information ecologies, which increasingly draw on information communicated through multiple media types and are mediated by an assortment of educational technologies. For example, students in flipped classrooms, a popular pedagogical approach [33], watch instructional video before class and work with their peers and instructors in hands-on problem-solving activities in class. While instructional video plays an important role in flipped classrooms, students continue to use traditional learning objects, such as syllabi, handouts, and textbooks. Educational technologies, such as learning management systems, discussion forums, and wikis, are also part of students' information ecologies (Figure 1). These heterogeneous sources are fragmented and loosely connected [11].

Re-designed tools may better support people by enabling meaningful connections across information ecologies. To explore this hypothesis, the first phase of the proposed research will provide a rich description of the current state of students' information ecologies, focusing on the degree of fragmentation in information ecologies and how students find, manage, and use their information ecologies. In the second phase, the solution space will be examined by re-designing and evaluating tools to address the tensions and challenges identified in the first phase. A lab-based evaluation will test the feasibility of the re-designed tools in helping people cohesively connect their information ecologies.

1.1 Scenario: Students' Information Ecologies

A scenario, based on interviews [11, 17] conducted with undergraduates as part of the ViDeX project,[1] may provide more insight into how and why students' interact with their information ecologies:

> Emily is a second-year undergraduate majoring in engineering, and is taking a flipped class on electromagnetics. She watches an instructional video before each class. Emily bookmarks information in the video that she finds confusing and would like to re-watch, and writes notes in her spiral notebook that she thinks may be useful when doing homework and studying for exams. She also writes notes in her notebook when reading her textbook, because she likes to keep all her annotations and notes in one place. Emily has access to the class discussion forum, but she does not like how difficult it is to keep up to date with new posts and replies. She is especially frustrated by how infrequently her instructor replies to posts. Consequently, Emily prefers to message her classmates on social media, where they share answers to the latest assignment by uploading snapshots of their homework with their cellphones. When she finishes her homework, Emily uploads it to the learning management system for grading. Emily knows the information she needs is available to her, but it is not easy to access, in part,

> because she cannot search across all the elements of her information ecology. This situation contributes to Emily's frustration that she cannot make sense of all the information that she could benefit from.

This scenario demonstrates the multiplicity of media, people, and tools that students interact with in their day-to-day learning activities and emphasizes the difficulties they face in searching, managing, and using their information ecologies.

2 RESEARCH QUESTIONS

The proposed research explores how students interact with and sustain their information ecologies by asking:

(1) What elements—information, people, and tools—constitute students' information ecologies, and what relationships exist between these elements?
(2) What tensions and breakdowns exist within students' information ecologies?
(3) How do students adapt and design their information practices when interacting with heterogeneous information?
(4) How can tools support more cohesive and connected information ecologies for students?

The research questions, methods, and analysis are informed by Activity Theoretical methods [20]. Activity Theory (AT) provides concepts that will be useful when making sense of students' learning activities, motivations, and tensions.[2] AT is a theoretical perspective that acknowledges that learning is actively constructed, involves interdependencies between information, people, and tools, and is pursued within spaces that in turn structure our activities.

A deeper understanding of the problem space is needed to inform the design of technologies with students' lived experiences in mind. I am motivated to contribute to critical discussions about how people manage diverse, distributed, conflicting information and weave heterogeneous information together when making decisions based on the material, cognitive, and social aspects of information.

3 PREVIOUS WORK

The proposed work builds upon the human-computer interaction and information retrieval research literature. There has been a substantial amount of interest in students' information practices; however, most research has not focused on heterogeneous information, people, and tools. Students' personal information management of text-based information, including activities for "finding, keeping, organizing, and maintaining information" [18], has been studied [29]. Similarly, students' annotation [25, 26, 43], clipping [27], and note taking [28, 34, 35] practices have been investigated. Scholars have explored these practices—annotation, for example— in non-text media; however, non-text-based works also focus on medium-specific information interactions, such as video [9, 12, 30]. While the research literature helps to explain why and how students interact with a specific medium, it is unclear how information practices translate to information ecologies comprised of audio, images, text, *and* video, resulting in calls to study how people interact with information across media [22, 39]. Now is the time to pursue

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this research agenda given how students are increasingly using heterogeneous information.

Improving search across information ecologies may help address the fragmentation problem [2, 13], but cross-media search remains a challenge. Searching across information ecologies requires techniques for representing and comparing the various types of media that comprise information ecologies. The dominant text-based approaches are not especially well-suited for audiovisual information and queries [24]. Video, for example, is a challenging medium to search given its streams of aural and visual information. The visual stream is comprised of a series of frames to be grouped into scenes, key frames to be selected, and people, places, and things within frames to be identified [37]. The aural stream of video also needs to be processed, often using speech recognition. There has been considerable effort to represent these information streams [38, 42]. How can advancements in federated and multimedia search be applied to context of the proposed research?

More than the content of information objects can be used to weave elements of information ecologies together. In addition to representing the content of objects, attempts have been made to represent how information objects are used [23, 36]. There have been attempts to incorporate interaction histories [40] to signal which parts of an object has (or has not) received attention in the past. Brown and Duguid [5], for example, argue that interaction histories provide traces that can be used for deciding how to interact with information. Interaction histories, such as shared annotations [28], can be found in some digital reading environments, and are beginning to appear in some video players, which display the most viewed [21] and annotated [8, 12] intervals of content. In the context of the proposed research, when made aware of the activities of other students, such as where in video they have highlighted, tagged, and written notes, students' information interaction can inform subsequent information use. More work is needed to explore the effects of guiding peoples' attention through interaction histories. The value of pre-existing annotations, for example, remains unclear. Shared highlights have been found to have no clear positive effect on reading comprehension [6, 7], but may support other learning processes and outcomes.

4 METHODS

The proposed research will be conducted as a two-phase study to investigate undergraduates' information practices (RQs 1–3) and how tools can help address the challenges students face in interacting with heterogeneous information (RQ4). In working towards the research questions, the proposed research will take a design-based research approach [4] by deploying ViDeX [15], a video player designed for active viewing [10]. Both phases of the proposed work will recruit students enrolled in courses using ViDeX.

In the first phase, students will be interviewed about the nature of their information ecologies, obtaining descriptions of the relationships between information, tools, and people using information world mapping (IWM)—an arts-based technique for eliciting visual representations of these relationships [16]. Throughout the semester, data will also be logged by ViDeX as students interact with instructional video, providing a second-by-second record of

activity. The analysis of the log data will identify patterns of information interaction which will complement the qualitative analysis of the interview transcripts. The combination of IWM and log data analysis will allow for the triangulation of multiple sources of data.

In the second phase, ViDeX will be re-designed to introduce new tools for addressing the tensions and breakdowns identified in the first phase of the study. For example, class materials may be woven with other elements of students' information ecologies, such as information snippets from the discussion forum, textbook, and instructional video that may otherwise remain unused fragments. Interaction histories [40] may also be displayed to guide students' information interaction and use. To evaluate the re-designed ViDeX, a lab-based study will be conducted.

5 PROGRESS MADE & FUTURE PLANS

Through my collaborations with the other members of the ViDeX team, I have begun to understand how students interact with heterogeneous information. In a study—the primary source for the earlier scenario—we explored students' note taking practices in flipped classrooms [11]. We found that students wove information from their information ecologies into their notebooks, which acted as a tapestry of diverse and distributed information.

I have also explored how video-based highlights, notes, and tags can be shared as interaction histories [8], and have found that annotations clustered around the same intervals of instructional video. This is evidence that students identified the same content as important or confusing, suggesting that students' may benefit from seeing each other's annotations. Future work could explore how students may use shared annotations when working towards different tasks, such as viewing video to prepare for class, homework, or exams, and how these traces could be connected to other information in students' ecologies.

A goal of the proposed work is to explore how the design of practices and systems can be improved through a perspective that is sensitive to the interactions within information ecologies, and how educational technologies can support students in weaving information, people, and tools together.

I plan to defend my dissertation proposal in the spring of 2019. The first phase of the proposed research will begin by the summer of 2019, and a manuscript dissertation will be defended by the 2020/2021 academic year. This dissertation will act as the basis for the development of educational technologies and other tools for bringing together diverse and distributed information.

6 CONCLUSION

Our lives are increasingly dependent upon an ability to find, manage, and use information. While there has been considerable attention paid to information overload, individuals now interact with diverse and distributed information, people, and tools. This demands renewed scholarly focus on shifts in information diversity and dispersion, not only information volume. The proposed work will investigate both the problem and solution spaces, aiming to make practical and theoretical contributions. Practically, the proposed work will act as a design guideline for educational technologies and other information systems. Theoretically, the proposed work will further develop the concept of heterogeneous information

by describing the challenges and opportunities people face when interacting with contemporary information ecologies. A deeper understanding of these tensions and breakdowns is needed to inform the design of technologies with individuals' lived experiences in mind. Managing information ecologies is a critical, transferable skill that requires improved support, as it is crucial to learning and participating in contemporary society.

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