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Undergraduate Students Experience Cognitive Complexity in Basic Elements of Library Research

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Abstract

Google's success in building a search engine that easily handles natural language, corrects spelling errors with intelligent "did you mean" prompts, and delivers reliably relevant search results, has led to trust in the search engine itself, along with self-confidence in users' searching skills. Although academic library search tools have attempted to replicate Google's form and functionality, students are often met with confusing, unexpected, or incorrect results. The online information seeking behavior of undergraduate students is a highly-studied topic across library literature, but the role that cognitive complexity plays in search remains largely unexplored. We use Cognitive Task Analysis (CTA) methodologies to study undergraduate College of Engineering and College of Sciences and Arts students' search processes. We may expect that undergraduate students experience cognitive complexity with more advanced search techniques, like proximity searching, truncation, wildcards, or Boolean expressions, for example. However, analysis reveals that undergraduate students experience cognitive complexity in basic elements of library research: a) deciding which terms to use, b) knowing if they are searching in the right place, c) examining each article to weed out less relevant articles, and d) evaluating the quality of a source. Our findings reveal a sizable disconnect between what librarians may expect are basic elements of the search process and what students experience as cognitively complex.

Introduction

As public internet search tools have become faster, more accurate, and more sophisticated over time, users' information searching behavior has also adapted. In particular, Google's success in building a search engine that easily handles natural language, corrects spelling errors with intelligent "did you mean" prompts, and delivers reliably relevant search results, has led to high trust in the search engine itself, along with high self-confidence in undergraduate students' searching skills. Libraries have developed tools like federated search, which allow searching across multiple data sources with one search string, and then uses custom algorithms to rank results. While federated searches are useful when one knows how to utilize them, the behavior of the search bar doesn't usually match the mental models that undergraduate searchers are accustomed to when using Google.

In human cognition, mental models are important schemas of the world that people use to reason, solve problems, and make inferences across situations [1]. When students apply their mental models of Google-like search expectations to single search bars on library websites or scientific databases, they are often met with confusing, unexpected, or incorrect results. The purpose of this exploratory study is to evaluate undergraduate College of Engineering and College of Sciences and Arts students' real-world search strategies during a library instruction session at Michigan Technological University (MTU). College of Engineering students comprise 60% of this STEM-focused, R2 institution's enrollment. By using Cognitive Task Analysis (CTA) methodologies to study their search processes, we first hope to identify which aspects of academic search students find cognitively complex, and then use our preliminary results to propose updated strategies for library instruction and search tool functionality. Students and instructors will be able to use information from this study to better understand how these gaps in search mental models contribute to cognitive complexity.

Literature Review

The online information seeking behavior of undergraduate students is a highly-studied topic across library literature. This literature review focuses on studies that examine how mental models affect search and those that consider how a lifetime of Google usage has shaped undergraduate students' search strategies.

Several studies correlate the quality of a searcher's mental model of a query with the quality of their search results. Whether the mental models are "robust," "strong," or "immature," researchers have found that the degree of effectiveness or success with search is dependent on the completeness or maturity of the searchers' mental models [1], [2], [3]. In addition, there are age-related differences in search mental models that affect how search techniques have evolved [4]. Although different from typical search mental models, Limas calls attention to the effective strategies that millennials and Gen Zers have independently developed and bring to everyday-life information-seeking [5]. Based on individual experiences, beliefs, and knowledge, search mental models are inherently complex, constantly evolving, and require refinement over time [6].

Academic libraries serve an important role in providing access to academic resources. However, researchers have found that searching for and finding the right information using library-sponsored search tools is not as intuitive as public search engines like Google or Google Scholar [4, 7]. For many reasons, Google is where a vast majority of students begin their research [8]. Bloom and Deyrup go so far as to call this Google-centric search behavior "endemic" and have coined it "Google Dependence." As a result, when students are presented with non-Google search bar situations, their Google mental model carries over and unexpected results may cause some distress [9]. For example, most library search tools misunderstand natural language searches and return incorrect results. Negative searching experiences like this sometimes lead searchers to think that the library just doesn't have any sources on their topic [10].

Other studies have shown that as Google's relevance ranking algorithms have improved, students seldom need to consult more than the first page of search results. This behavior extends to how they evaluate library search tool results [11]. Students' typical strategies in non-Google search bars likely return an unfamiliar mixture of source types [12] that require more time for evaluating quality and relevance [10]. Oh and Colón-Aguirre have also found that students experience difficulty describing and applying evaluative criteria to sources [13]. Google's influence shapes searchers' types of searches, how many searches they try, and the overall length of the research session [13]. And, simultaneously, undergraduate students overestimate their searching skills [14], have difficulty understanding library information structures, and struggle to meaningfully engage with scholarly literature [9]. In short, a chasm exists between what librarians think students know and their actual skills [15].

Although the online information seeking behavior of undergraduate students is a highly-studied topic across library literature, the role that naturalistic cognitive complexity plays in search remains largely unexplored. Studies on search task complexity, although contrived in lab-like environments, have provided some parameters for defining different levels of complexity [16, 17]. In this exploratory study, we delve into the cognitively complex pain points that our undergraduate College of Engineering and College of Sciences and Arts students encounter when searching.

Methodology

Cognitive Task Analysis (CTA) is a technique used to study and understand the mental strategies that people use to complete tasks [6]. It is useful in a variety of fields, as it can help to identify cognitive demands, mental workload, and potential sources of errors or mistakes. By understanding these factors, CTA can help us design more effective and efficient learning experiences, tools, training programs, and work environments. If we can understand the psychology of a task through observing how people think and act in real-world situations, we can devise more effective solutions for the real problem [18].

In this study, we use CTA to explore STEM students' real-world pain points with search. Fourteen undergraduate students from the College of Engineering and the College of Sciences and Arts completed several library searches during one library instruction session. We used a self-report method for knowledge elicitation and data collection. Our Institutional Review Board (IRB) confirmed that an IRB review was not needed since we used only de-identified data for this study. Before searching, students were asked to answer two written questions about their real-world experiences with searching for resources:

Q1: What do you think are 3-5 hard things about searching?
Q2: Which ones are cognitively complex? (star) Why?

We framed these particular questions to pinpoint which aspects of search present the hardest cognitive challenges (pain points) for engineering and STEM undergraduates. In answer to a question about the meaning of 'cognitive complexity,' we mean the type of thinking that involves judgments, problem-solving, or assessment. The students were then asked to perform several searches and reported on the questionnaire how they searched for academic materials. The worksheet asked about their typical search strategies, directed them to find a good journal article on a particular topic, and then the students documented their strategies and results. We collected the questionnaires after the session and analyzed the students' answers. To help identify common themes, we compiled their answers to Q1 and Q2 using both a task diagram and a concept map in Fig. 1 and 2.

The goal of a task diagram is to get an initial overview of a cognitive task and then identify the challenging aspects, or cognitive complexity. It is important to note that this exercise requires tasks that are cognitively challenging. Tasks that are too vague or too simple will give less meaningful and vague data.

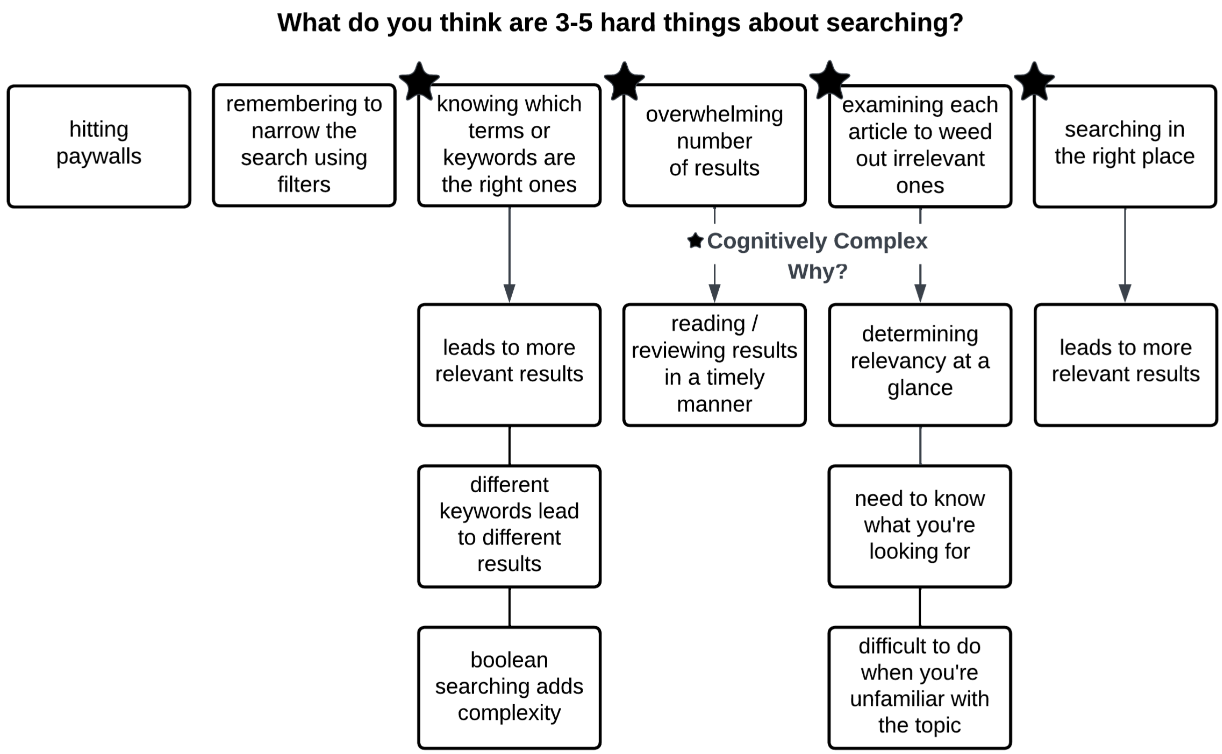

Fig. 1. Task diagram of fourteen undergraduate College of Engineering and College of Sciences and Arts students' answers to *Q1:* What do you think are 3-5 hard things about searching? And *Q2:* Which ones are cognitively complex? (star) Why?

To create this study's task diagram shown in Fig. 1, we first systematically worked through the answers to Q1 and sorted the data into categories. Although the words used to describe the challenging aspects of search differed slightly among participants, the top-level categories reflect the common themes as analyzed by the author. Following best practices for this technique, we made multiple passes through the data in case new insights popped out [6]. We then placed the final categories at the top level of the diagram. Next, using the answers to Q2, we placed stars beside the aspects that students identified as cognitively complex. The answers to Q2's second part, "Why?" are connected to the cognitively complex activity with arrows and then with lines to convey that the answers all belong to the same activity. We chose a task diagram to elicit and distill the cognitive complexities of undergraduate search experiences, and then paired it with a concept map to link and define the relationships between concepts.

Concept maps use a combination of concept nodes and thoughtful link labels and lines that express meaningful relationships among concepts [6]. The concept map shown in Fig. 2 was made using CmapTools, a free online tool for creating and sharing concept maps [19]. Concept maps are valuable in CTA because they provide a visual representation of knowledge structure, assist in analyzing knowledge relationships, and help communicate complex information more clearly. Concept maps enhance both the audience's understanding of a concept and give the map builder deeper knowledge and insights during the mapping process.

To create the concept map shown in Fig. 2, we placed the most important concepts from our study near the top of the diagram. In our case, these are the cognitively complex categories identified in Q2. Next, we added participants' answers from the second part of Q2, "Why?" and linked nodes together with short words or phrases that define the relationship between the concepts. Finally, we refined our initial map. To do this, we added, subtracted, or changed link

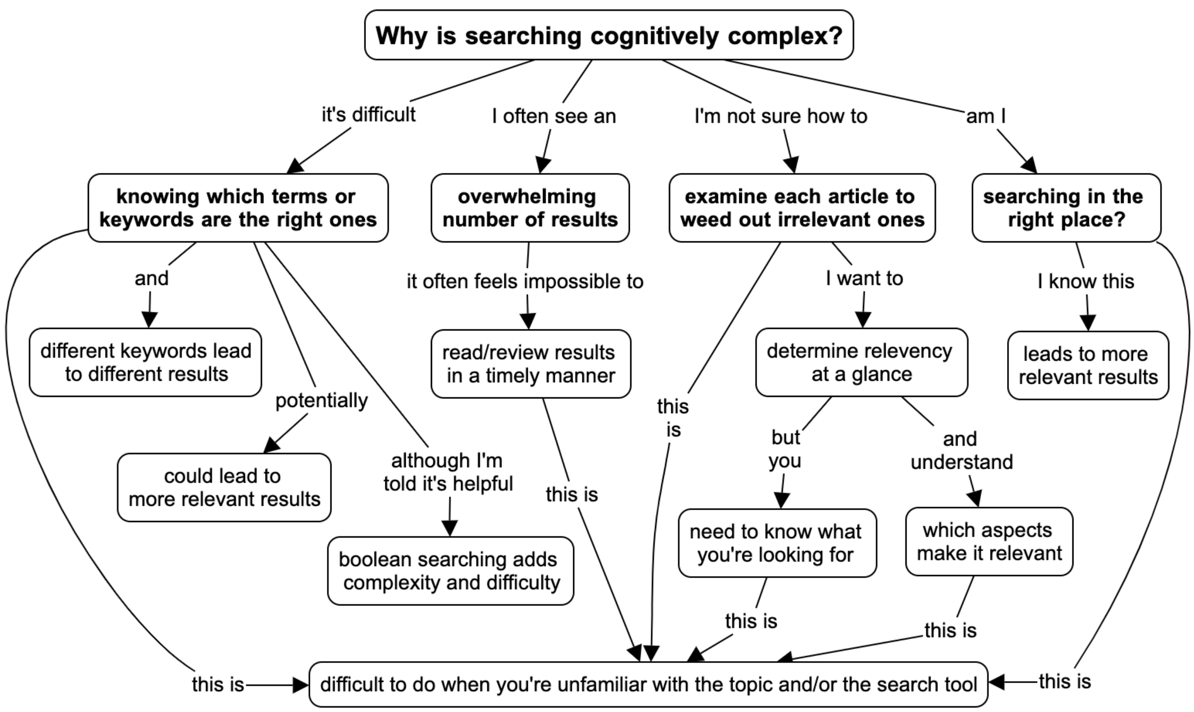

Fig. 2. Concept map using data points pulled from the task diagram in Fig. 1. Concept maps can visualize a story and reveal connections between and among tasks that are not readily apparent with other methods.

labels and linked nodes. We also looked for opportunities to add cross-links between nodes in different sections of the concept map.

Results

The top row of the Fig. 1. task diagram includes the main themes identified in Q1 and highlights the themes identified as 'cognitively complex' in Q2 with a star. Boxes that answered the 'Why?' for cognitive complexity branch downward in subsequent rows. Based on the overlap across participants, our engineering and STEM students identified that the four most cognitively complex aspects of searching are a) knowing which terms or keywords are the right ones, b) overwhelming number of results, c) examining each article to weed out irrelevant ones, and d) knowing whether they are searching in the right place.

Data is also represented using a concept map in Fig. 2. Concept maps visually represent a story and reveal powerful connections between and among tasks that are not readily apparent with other methods [6]. Connecting the study participants' experiences resulted in a much more detailed view of the cognitive complexity of library search for these undergraduates. Task diagrams and concept maps are two common tools used in CTA that provide complementary information via different data organization formats. Using both together -- the outline of the main ideas represented in the task diagram and the detailed, interconnected story represented in the concept map -- successfully captured elements of undergraduate students' mental models for search.

Discussion

Our data suggest a disconnect between students' mental models of search using library search tools and Google Scholar as others have found [4]. We may expect that undergraduate students experience cognitive complexity with more advanced search techniques, like proximity searching, truncation, wildcards, or Boolean expressions, for example. However, analysis reveals that undergraduate students experience cognitive complexity in basic elements of library research: a) deciding which terms to use, b) knowing if they are searching in the right place, c) examining each article to weed out less relevant articles, and d) evaluating the quality of a source. Our findings reveal a sizable disconnect between what librarians may expect are basic elements of the search process and what students experience as cognitively complex.

This has important implications for current information literacy (IL) education. The cognitive complexities revealed in this study identify potential gaps in how academic searching is taught. The Google-centric searching behavior mentioned earlier, and cast in a somewhat negative light, doubles as a wealth of experience and knowledge that students bring into the classroom. Instead of assuming that students are complete novices, with deficits that need fixing by librarians, what if instructors instead help students focus on building their own representations and upgrading their pre-existing knowledge (schemas) [20, 21]?

The Theory of Constructivism encourages individuals to create their own meaning of new material that builds on their prior knowledge by engaging in "authentic" tasks in interactive social environments [22, 23]. Active learning principles have been incorporated into information literacy education and library research instruction in a general manner. However, a robust, constructivist approach goes a few steps further by acknowledging that students bring their own positionality with them into the classroom. How we structure the library session matters. When introducing an instruction activity, for example, acknowledge that learners construct their own understanding of information by actively engaging with it and relating it to their prior knowledge and experiences. The main activity will ideally encourage students to actively engage with information, collaborate with peers, reflect on their learning process, and construct their own understanding of information literacy concepts. Leveraging these powerful elements of existing mental models, and putting them into practice in a classroom, enhances the learning experience for everyone, including instructors. Knowing when, how, and to what extent students use particular heuristics to more easily process information, are newer areas of information literacy research that require exploration [24, 25].

The cognitive complexities revealed in this study help to identify gaps in how academic search tools appear and function. Library search tools that provide a searching interface for multiple types of subscription resources (articles, databases, data, books, ebooks, media, and more) changed their look to appear more Google-like, as Google became the default internet search tool [26]. To better appeal to Google users, libraries updated their search bars to be less intimidating, less complicated, more functional, and more convenient for accessing library resources. Unfortunately, since the library search bar does not follow the same searching rules as Google, these benefits typically fail when undergraduates use them.

Consideration of undergraduate students' mental models for using search bars could inform and improve library search tool interface design and, by extension, functionality. Implementing these models could reduce the cognitive complexity enough to make it more user-friendly and more compatible with public search tools like Google. If we could reduce the cognitive complexity that students experience when using library search tools, we may also remove any hesitation that they feel when searching with a non-Google interface.

Library search tools offer default settings as well as customizations for interface display and functionality. For successful customization, however, it is essential to understand how searchers use particular mental models to find the information they need [25]. To collect this vital information, it is necessary to expand this study's design beyond self-reporting and include several different knowledge elicitation tools in order to more accurately understand cognition in context.

Conclusion

This exploratory CTA study provides data that highlight several areas where engineering libraries may focus their efforts to improve student search outcomes. It also confirms and extends existing literature in this area [7, 10]. We are planning a follow up study that will explore how a larger group of undergraduate students use public search tools, the library's search tool, what they expect from each one, and where cognitive complexity enters into their decisions about search. We will also include professional librarians in the study in order to compare and contrast expert and novice approaches. In-depth CTA interviews with individual undergraduate students and librarians will elicit more detailed and rich descriptions about searching behavior that we could not capture via this small preliminary study. We will also need input and feedback from other MTU user groups before making changes to our library's search functionality and appearance. Once the data is collected, we could develop, test, and launch a search interface that is more flexible and more compatible with user groups with varying levels of experience with search. While there are currently technological limitations with library search tools, new research on AI in knowledge discovery sounds promising. What if instead of using a library catalog to locate a resource, searchers could navigate the entire collection using machine learning tools [27]? Finally, combining ever-evolving technology with robust constructivist teaching methods may help close the gap between librarians' assumptions and students' actual search skills. This pairing could make library research more dynamic, relevant, time-saving, and less cognitively complex.

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