OrgBox: A Knowledge Representation Tool to Support Complex Search Tasks

Bogeum Choi, Jaime Arguello, Robert Capra and Austin R. Ward
School of Information and Library Science, University of North Carolina at Chapel Hill
[bochoi,jarguello,rcapra,austinrw]@unc.edu

ABSTRACT

Current search systems are effective in helping users complete simple search tasks (e.g., fact-finding). However, they provide less support for users completing complex search tasks. Complex search tasks involve a diverse set of cognitive and metacognitive activities, such as goal-setting, organizing information, drawing inferences, monitoring progress, and updating mental models. We report on a lab study ($N = 32$) that investigated the uses and influences of a novel *knowledge representation* tool called the "OrgBox", developed to support searchers with complex tasks. The OrgBox was integrated into a custom-built search system and allowed participants to save information by drag-and-dropping textual passages into the tool, organize passages into "boxes", and make notes on passages and boxes. The OrgBox tool was compared to a baseline tool (the "Bookmark") that allowed participants to save passages, but not organize them nor make notes. We investigate four research questions. In RQ1, we investigate the effects of the knowledge representation tool on participants' post-task perceptions. In RQ2-RQ4, we investigate: (RQ2) how participants used different features of each tool; (RQ3) the perceived benefits and challenges of each tool; and (RQ4) the influences of each tool on the approaches taken by participants to complete the task. To address RQ2-RQ4, we conducted a qualitative analysis of participants' responses during an exit interview. We discuss implications from our results for designing tools to support users with complex search tasks.

ACM Reference Format:
Bogeum Choi, Jaime Arguello, Robert Capra and Austin R. Ward. 2021. OrgBox: A Knowledge Representation Tool to Support Complex Search Tasks. In *Proceedings of the 2021 ACM SIGIR Conference on Human Information Interaction and Retrieval (CHIIR '21), March 14–19, 2021, Canberra, ACT, Australia.* ACM, New York, NY, USA, 10 pages. https://doi.org/10.1145/3406522.3446029

1 INTRODUCTION

Current search systems are effective in helping users with simple search tasks (e.g., fact-finding). However, they provide less support for users during complex search tasks that involve a diverse set of cognitive and metacognitive activities, including goal-setting, making inferences, synthesizing, monitoring progress, and updating mental models and search strategies. One approach to supporting searchers with complex tasks has been to develop *search assistance* tools that are *complementary* to the search interface [1, 8–10, 16, 28].

In this paper, we present research on a novel *knowledge representation* tool called the "OrgBox" (Figure 1). We report on a user study ($N = 32$) that investigated the uses and influences of the OrgBox tool (compared to a baseline tool) during complex search tasks. The OrgBox was integrated into a custom-built search system and was designed to help searchers easily save and organize information by drag-and-dropping textual passages from a landing page onto logical groupings called "boxes". Using the OrgBox, participants could add, delete, and edit passages and boxes; add notes to passages and boxes; indent passages within a box to create hierarchies; move passages between boxes; and (re-)arrange boxes vertically and horizontally. These features were designed to support users with developing sub-goals, saving and (re-)organizing information, representing relationships, and monitoring their progress. To study the uses and influences of the OrgBox tool, we compared it against a baseline tool called the "Bookmark". The Bookmark tool allowed participants to drag-and-drop textual passages into a vertical list but not group them, rearrange them, nor make notes.

We refer to the OrgBox as a knowledge representation tool because it enables a searcher to *externalize* and *modify* their mental representation of a complex domain as they gather information. While there are numerous theories on how knowledge is represented in the human mind, fundamental components include facts, concepts, and relations [4, 6, 20]. Features of the OrgBox allowed participants to represent important topics and relations among them. Additionally, we designed the OrgBox to support different cognitive and metacognitive activities involved in complex search tasks. In terms of metacognitive activities, prior work suggests that external knowledge representations can support goal-setting, monitoring progress, and revising approaches to the task [27].

Participants in our study completed two complex search tasks, one with the OrgBox and one with the Bookmark tool. Our search tasks were situated in the following scenario. Participants were asked to imagine being a journalism student with an assignment to write a 30-page paper on a given complex topic in U.S. politics (abortion or gun control). During each task, participants were asked to gather information using a custom-built search engine and the assigned tool. During the *search phase* of each task, participants were given 40 minutes to gather information. Then, during the *outline generation phase* of each task, participants were given 15 minutes to produce an outline for the hypothetical 30-page paper.

Our study investigated four research questions. In RQ1, we investigate the effects of the interface condition (OrgBox vs. Bookmark tool) on participants' post-task perceptions. To address RQ1, we analyzed participants' responses to a post-task questionnaire about their perceptions of the task and the provided tool. We asked about

CHIIR '21, March 14–19, 2021, Canberra, ACT, Australia

ACM ISBN 978-1-4503-8055-3/21/03…$15.00
https://doi.org/10.1145/3406522.3446029

perceptions of difficulty, satisfaction, knowledge gains, etc., and whether the provided tool was helpful in supporting different cognitive and metacognitive activities (e.g., organizing information, drawing inferences, goal-setting, monitoring their progress, etc.) In RQ2-RQ4, we investigate: (RQ2) how participants used different features of each tool (i.e., for what purpose); (RQ3) the perceived benefits and challenges associated with each tool; and (RQ4) how each tool influenced the approach participants took during the task. To address RQ2-RQ4, we conducted a qualitative analysis of participants' responses during a semi-structured exit interview.

2 RELATED WORK

The OrgBox tool was developed to help searchers externalize knowledge structures while gathering information on a complex topic. Thus, we build on prior work on knowledge representation tools.

Research in cognitive psychology argues that externalizing knowledge structures can help individuals store, structure, utilize, and acquire knowledge [11, 17]. Additionally, creating visual knowledge representations can help individuals create more coherent representations of *new* information [11]. In education, it is argued that externalizing knowledge can help students organize, analyze, evaluate, and generate ideas [5, 12, 23]. Bransford et al. [2] summarizes several studies that found that learners who categorized information were more likely to recall it. Tergan [23, 24] argues that computer-based concept mapping tools can help learners: (1) organize information, (2) maintain awareness of knowledge gaps, (3) evaluate the quantity/quality of one's own knowledge, (4) generate new knowledge, and (5) communicate knowledge to others.

More closely related to IIR, the role of knowledge structures has also been studied in the context of *sense-making*, which involves "making sense" of a complex domain or task. Russell et al. [18] originally conceptualized sense-making as a cyclical process (the so-called "learning loop complex"). The first stage involves searching for a good representation (i.e., the "generation loop"). The second stage involves finding and encoding information using the latest representation (i.e., the "data coverage loop"). The data coverage loop often involves identifying information that does not fit neatly into the latest representation (i.e., the "residue") resulting in a need to adjust the current representation to have better coverage (i.e., the "representation shift loop"). Russell et al. [18] called for a tighter integration between IR systems and knowledge representation tools. In a position paper, Stefik et al. [22] argued that when a sense-making task is difficult, sense-makers use *external* representations to store information for repeated manipulation.

Crescenzi et al. [3] conducted a lab study to learn about the design requirements for systems that provide an integrated search interface and note-taking tool. The study involved a qualitative analysis of handwritten notes made by participants during exploratory search tasks. Results found that participants used different structures to organize information (e.g., single-level lists, multi-level lists, and clusters). Additionally, simple structures (e.g., lists) were more common at earlier stages, while complex structures (e.g., clusters) typically emerged as the search progressed.

Prior research has developed and evaluated a wide range of tools to help users save and organize search results. Hearst and Degler [9] developed a tool similar to our OrgBox tool. The tool allowed participants to save, delete, visually group, and annotate documents. A usability test with legal analysts found that participants responded favorably to the tool. Additionally, participants expressed a desire for additional features, such as being able to search within specific groups of documents and label relations between groups. Bae et al. [1] developed the Visual Knowledge Building (VKB) system, which allowed users to group and annotate documents. However, the tool was not integrated with a search system. Results from a usability study found that some participants preferred to organize documents as they evaluated their relevance, while others preferred doing document triage first and organization second. Hinckley et al. [10] designed the InkSeine system, which allowed users to organize search results into "piles" and add notes. The Sandbox system was developed to help intelligence analysts with complex information-seeking tasks [28]. The tool allowed users to save, group, and annotate search results. Results from a small usability study found that the tool allowed participants to examine more documents in less time. In the context of multimedia search, prior work developed the ViGOR system for video search [8] and ImageGrouper for image search [16]. Both systems allowed users to save search results into groups and use groups as queries.

3 METHODS

3.1 Study Overview & Protocol

To address RQ1-RQ4, we conducted a laboratory study with 32 participants (26 female). Participants were recruited using an opt-in mailing list of employees from our university. Participants included 17 student employees and 15 non-student employees. Their ages ranged from 18 to 66 ($M = 29.16$, $S.D. = 11.73$).

The study protocol proceeded as follows. After providing informed consent, participants completed a demographics questionnaire. Then participants completed two experimental tasks that followed the same sequence of steps. First, participants were asked to read the task description aloud. Participants were asked to imagine being a journalism student with an assignment to write a 30-page paper on a specific topic of debate in U.S. politics. Participants were instructed that the objective of this hypothetical assignment was to give them experience conducting journalistic research using a news archive. The task description also specified that they would have 40 minutes (max) to gather information and 15 minutes (max) to create an outline of the hypothetical 30-page paper in an external electronic document. After reading the task description, participants watched a 5-minute video introducing the search system and the tool associated with the task (the OrgBox or Bookmark tool). Then participants completed the search and outline generation phases of the task. After the outline generation phase, participants completed a post-task questionnaire. Finally, after completing both experimental tasks, participants completed an exit interview that asked about their experiences interacting with the OrgBox and Bookmark tools.

The study involved two tasks (abortion and gun control) and two tools (OrgBox and Bookmark). More detailed information of the tasks and tools is provided in the following sections. There were four combinations of task and tool. Task and tool were counterbalanced (i.e., 16 participants were assigned each task/tool combination). We also balanced the order of presentation for the four combinations—8 participants were assigned each order (e.g., Abortion/OrgBox followed by Gun Control/Bookmark). Participants received US$40 for participating.

3.2 Tasks

To contextualize our tasks, participants were asked to imagine being a journalism student with an assignment to write a 30-page paper on a topic of debate in U.S. politics. Participants were told that the assignment's objective was to give them practice conducting journalistic research using a news archive. Participants were informed that they would have 40 minutes (max) to gather information using a custom-built search system and 15 minutes (max) to generate an outline for their hypothetical paper. Participants were also told that they would be given access to a collection of news articles published by the Washington Post between 2012-2017. To provide more guidance, participants were instructed that the hypothetical paper (and outline) should: (1) focus on news reporting relevant to the collection's time period (2012-2017); (2) aim for both depth and breadth; and (3) include topics of interest to news readers. The final task descriptions were as follows.

Abortion Task: Abortion is probably one of the most controversial subjects in modern society. It involves a number of complex questions including philosophical, legal, and religious issues (among others) related to the deliberate ending of pregnancy before normal childbirth. Public opinions are polarized. People have strong feelings for or against this subject. That's why writing a good paper on requires in-depth research of existing newspaper reports. You will need to find a decent number of relevant articles touching on different aspects of the debate in order to create a comprehensive and well-balanced paper.

Gun Control Task: Gun control (or gun rights) has been considered one of the most controversial debates of our time. It involves a number of complex questions including ideological, legal, and social issues (among others) related to regulating the right of individuals to possess guns. Public opinions are...[same as above].

During the outline generation phase of each task, participants were asked to use the information gathered to produce an outline of the paper. Participants were instructed that the outline should provide the overall structure and flow of the paper, describe the topics (and sub-topics) to be covered in the paper, and provide short descriptions of the content of each (sub-)section.

3.3 Search Tools

For one task, participants used the OrgBox to organize the information found. For the other task, they used the Bookmark.

Search System: To search for information, participants used a custom-built search system. The system was developed using Lucene and provided access to the TREC Washington Post Corpus, which contains 671,947 news articles published between 2012 and 2017. The system allowed participants to issue queries and filter search results by publication year and topical category. The search interface included a button next to the search bar labeled with the name of the tool associated with the experimental condition (i.e., OrgBox or Bookmark). Clicking this button displayed the tool in a pop-up browser window. Participants used two monitors, which allowed them to position the search system and tool side by side.

OrgBox Tool: Figure 1 illustrates the OrgBox knowledge representation tool. The OrgBox tool was designed to help participants externalize their understanding of the assigned topic as they searched for information. Using the OrgBox, participants could not only save the information found but also organize it into clusters

Figure 1: OrgBox tool

(referred to as "boxes"). To create a new box, participants could either click a "create new box" button or drag-and-drop text from a landing page into the OrgBox. Either action triggered a pop-up window that prompted participants to provide a title for the new box. Participants could add "items" to an existing box by drag-and-dropping highlighted text from a landing page into a box. Each added item consisted of three components: (1) the title of the landing page, (2) the textual passage that was drag-and-dropped, and (3) a note added by the participant. When adding a new item to a box, participants were prompted to add a note in a pop-up window. Participants were able to create/add as many boxes and items as desired and were also able to delete and edit boxes and items. Participants could also move items between boxes and organize items within a box in a two-level hierarchy. Finally, participants could organize boxes spatially by moving them vertically and horizontally.

Bookmark Tool: The Bookmark tool was designed to serve as a baseline and was therefore more rigid than the OrgBox tool. Like the OrgBox tool, participants were able to save information "items" by drag-and-dropping text from a landing page into the Bookmark tool. Each item consisted of two components: (1) the title of the landing page and (2) the text that was drag-and-dropped. Unlike the OrgBox tool, however, participants were not able to organize items into clusters (i.e., boxes). Saved items were stacked vertically in the order in which they were added. Participants were able to delete previously added items, but not able to make notes about items nor re-order them.

3.4 Post-task Questionnaire

After completing each task (search + outline generation phase), participants completed a post-task questionnaire. Participants indicated their level of agreement with statements on a 7-point scale from strongly disagree (1) to strongly agree (7). The full text of the post-task questionnaire is available online.

The post-task questionnaire was divided into three parts. The first part included 14 items that measured participants' perceived knowledge increase in the task domain (1 items), interest increase (1 items), difficulty (4 items), satisfaction (4 items), and self-assessed

expertise in the task domain (4 items). Based on Cronbach's alpha, the 4 items for expertise had high internal consistency ($\alpha = 0.92$). Thus, we averaged responses to these items to form one expertise measure. The items for difficulty and satisfaction had lower internal consistency, so we treated responses individually.

The second part of the post-task questionnaire included 10 items that measured participants' perceptions of the outline produced. These items focused on perceptions of the outline having a clearly defined scope, breadth, depth, a balance of breadth and depth, a logical organization, and supporting evidence from the articles found. These 10 items had high internal consistency ($\alpha = 0.90$). Thus, we averaged responses to form one "outline quality" measure.

Finally, the third part of the post-task questionnaire included 26 items that measured participants' perceptions about the tool (i.e., OrgBox or Bookmark tool) helping them with specific cognitive and metacognitive activities. These items were adapted from those used in McCardle and Hedwin [15]. We included items that measured the extent to which the tool helped participants with: (1) initial *planning* on how to approach the task (4 items), (2) *connecting* ideas (4 items), (3) *organizing* the information found (4 items), (4) search-oriented *goal-setting* (3 items), (5) *monitoring* their progress (3 items), (6) *evaluating* the information found and their approach to the task (3 items), and (7) *updating* or *revising* their understanding of the task and their goals (5 items). All groups of items had high internal consistency ($\alpha \geqslant 0.90$). Thus, we averaged responses to these items to form 7 distinct measures.

3.5 Qualitative Analysis

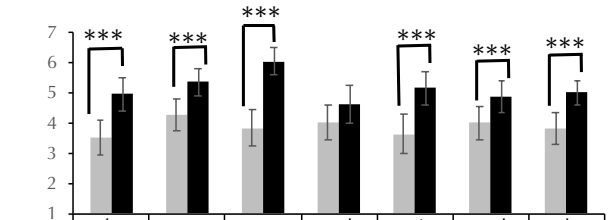
To address RQ2-RQ4, we performed a qualitative analysis of participants' responses during the semi-structured exit interview, which asked about their experiences interacting with both tools (OrgBox and Bookmark). The exit interview focused on: (1) uses of different features of each tool, (2) benefits and challenges of each tool, and (3) the influences of each tool on the participant's approach to the task. Our qualitative analysis was performed using the interview data from 16 (out of 32) participants. We chose participants 1-16, for which the task/tool orders were balanced. We decided to code only 16 (out of 32) interviews because code saturation was reached after coding the 12th interview (i.e., no new codes were introduced) [7, 19].

The analysis proceeded as follows. First, two of the authors (denoted as coders A and B) worked independently using data from four participants to develop codes associated with RQ2-RQ4. Next, both coders met to combine their individual coding schemes into one. At this point, some codes were re-defined, merged, and dropped. Next, coder A coded the remaining 12 participants and introduced a few new codes to reflect new phenomena encountered. Finally, coder B reviewed all of coder A's annotations (all 16 participants). Any disagreements were resolved through discussion.

4 RESULTS

4.1 RQ1: Effects on Post-task Perceptions

To address RQ1, we analyze the effects of the knowledge representation tool provided (i.e., OrgBox vs. Bookmark) on participants' post-task perceptions. To test for significance, we used multi-level modeling and treated *participant* as a random factor (i.e., random y-intercept) because knowledge representation tool was a within-subjects factor. The knowledge representation tool did *not* have significant effects on perceptions related to difficulty, interest/knowledge increase, domain expertise, nor satisfaction with the search process and the quality of the outline. However, as shown in Figure 2, the knowledge representation tool had significant effects on participants' perceptions of the tool being helpful in supporting different cognitive and metacognitive activities during the task. Participants perceived the OrgBox as being more helpful in supporting the cognitive activities of organizing information ($\beta = 2.211$, $S.E. = 0.326$, $p < .001$) and making connections ($\beta = 1.0781$, $S.E. = 0.274$, $p < .001$). Similarly, participants perceived the OrgBox as being more helpful in supporting the metacognitive activities of planning ($\beta = 1.445$, $S.E. = 0.266$, $p < .001$), monitoring their progress ($\beta = 1.521$, $S.E. = 0.256$, $p < .001$), and updating their mental models and strategies ($\beta = 1.181$, $S.E. = 0.264$, $p < .001$). The effects on goal-setting were marginally significant ($\beta = 0.572$, $S.E. = 0.296$, $p = .062$).



	plan	conn	org	goals	monitor	eval	update
book.	3.50	4.27	3.82	4.04	3.64	4.00	3.81
org.	4.95	5.34	6.03	4.62	5.16	4.89	4.99

Figure 2: RQ1: Effects on post-task perceptions. Means and 95% CIs. Symbol '*' denotes significant differences at the $p < .001$ level.**

4.2 RQ2: Uses and Workarounds

In RQ2, we analyzed 16 participants' responses during the exit interview to gain insights about how they used features of the OrgBox (OB) and worked around limitations of the Bookmark (BK). In the analyses presented below, we discuss the main findings from our qualitative analysis and include the number of participants who discussed each point.

4.2.1 Use of OrgBox (OB) Features. Across the interviews, participants discussed their use of five main features of the OB: (1) notes, (2) spatial organization, (3) personalized labels, (4) item hierarchies, and (5) scratch space for text.

Notes: Participants described four different ways in which they used the notes feature. First, participants (n=6) described using the notes to add a brief, general description of the saved passage or the source article from which the passage was extracted. Second, participants (n=5) mentioned using the notes to document how they planned to use the passage in their outline. Third, participants (n=3) discussed adding notes to document *why* they thought the passage was useful (i.e., noting relevance criteria). Fourth, participants (n=2) mentioned adding notes to describe connections or relationships with other saved passages.

Spatial organization: Several participants (n=7) mentioned using the OB's ability to move things around spatially (i.e., moving boxes vertical/horizontally and items between boxes). Participants (n = 4) mentioned (re)arranging the boxes vertically/horizontally to reflect either the flow of their search or the flow of their outline.

One participant (P16) mentioned positioning two boxes side-by-side to make comparisons between ideas more effectively. Lastly, participants (n = 3) mentioned moving passages within a box or between boxes. This occurred when participants realized that they could create a better flow by relocating a passage within a box or when they realized that an item was more closely related to items in another box. For example, P2 said *"You could also make it flow not only hierarchically but list wise. You could make it flow to your different topics, like move it to different boxes."*

Personalized label: Participants (n = 5) discussed changing the title of boxes or items from their default values for three reasons: (1) to better describe the contents of a box or item, (2) to summarize a passage, or (3) to reflect on what a passage meant to them. For example, P12 said *"I had changed the titles for them to be more meaningful to me so as I was trying to pick up which topics I wanted to focus on."*

Hierarchy: Participants could arrange items within a box in a two-level hierarchy. Participants (n=7) discussed creating hierarchical structures to represent relationships between ideas. Specifically, they used hierarchical relations to differentiate main points from subpoints and general ideas from examples.

Scratchpad: Two participants mentioned that they used a box as a note-taking space. In both cases, they made notes about how they planned to use the information saved in their boxes for their outline. For example, P5 said *"I created a new text box and I typed in, okay, this is what I want to say first. Go back to this box, [then] go back to this box. I want to say this next."*

4.2.2 Bookmark (BK) Workarounds. We also found that participants used workarounds to overcome the BK's lack of support for organizing information. We identified two ways in which participants tried to create some kind of structure in the BK. First, participants (n = 2) mentioned organizing passages by source. They extracted all the passages relevant to different subtopics from one article, moved on to the next article, and did the same. Although this allowed the passages from the same article to be kept near each other, it was not the same as grouping by topic. Additionally, participants (n = 3) mentioned searching for passages on each topic one-at-a-time (i.e., having the vertical order of passages in the BK be grouped by topic)

4.3 RQ3: Benefits and Challenges of Tools

In RQ3, we present a qualitative analysis of the interview data from 16 participants to investigate the perceived *benefits and challenges* of the OrgBox (OB) and Bookmark (BK) tools.

4.3.1 Benefits of the OB. During the interviews, participants described benefits of the OB related to: (1) learning, (2) cognitive activities, (3) metacognitive activities, (4) leveraging information found serendipitously, and (5) visually representing knowledge.

Learning: Participants described four types of learning activities supported by the OB: (1) identifying important topics, (2) identifying relationships, (3) synthesizing and internalizing, and (4) organizing and evaluating. First, a number of participants (n = 6) noted that the OB helped them identify important topics. Specifically, they described how the boxes allowed them to keep track of recurring themes and helped them select topics to focus on.

Second, participants (n = 5) mentioned that the OB helped them see relationships among ideas. For instance, P15 reported finding a passage that could fall under two boxes, which made her realize a connection between topics.

Third, several participants (n = 5) mentioned benefits of the OB related to internalizing information and synthesizing (i.e., putting things together to form a whole). Participants reported that the OB helped them get a big-picture understanding by presenting different clusters of related topics in one place. For example, P14 said *"the feature where you can move things around and start to create an outline, obviously, it's going to make you think about [...] how things are organized as a whole."* Another participant P1, described how the OB notes feature helped her summarize passages in her own words. P1 referred to this process as *"pre-synthesizing"* (i.e., synthesizing before the outline generation phase).

Fourth, many participants (n = 8) mentioned that the OB helped them organize passages as they completed the task and to (re)evaluate the "fit" between specific passages and their existing set of boxes. Participants could (re)organize passages such that a specific passage could be placed where it made the most sense, which allowed them to keep the topic groups more cohesive. For example, P2 said *"I had my sub-headings. And within the sub-headings, I put my sub-sub-headings. I could further classify those, so it was more organized and concise and consolidated."* Activities such as organizing information, internalizing information through note-taking, and evaluating the topical cohesion of clusters demonstrate that the OB encouraged participants to more actively and deeply interact with information, which can lead to deeper learning.

Cognitive activities: Participants described four main categories of cognitive activities that were supported by the OB: (1) classifying and sorting, (2) remembering and navigating, (3) saving switching costs, and (4) creating the outline.

First, several participants (n=3) mentioned that the OB helped them define specific sub-topics of interest and classify passages into those sub-topics. For example, P1 said *"It helped because I was able to bucket things that I was finding."* Similarly, P4 said *"It did help me sort through the raw information that I was finding into where I thought it was associated best with, the things that it matched with."*

Second, some participants (n = 3) mentioned that the visual cues in the OB (i.e., boundaries and the relative position of boxes) helped them navigate the OB and locate specific information. Additionally, the textual cues in the OB (i.e., titles and notes) helped them remember the context in which they saved certain passages. Participants found these visual and textual cues especially useful during the outline generation phase because it saved them time and effort in: (1) making sense of what they had saved and (2) creating the structure for the outline. For example, P9 stated: *"It definitely helped me find 'Here's what I was doing.' [...] I was putting what I was thinking my outline paper was gonna be about, so I knew exactly where to look for, whereas [with the] bookmark, you just had to scroll through all of the things that you had bookmarked."*

Third, statements from participants (n = 6) suggest that the OB made it easier and more efficient to *switch* between different cognitive activities during the task. Complex information-seeking tasks involve a range of cognitive activities such as searching, reading, evaluating, organizing, and writing. During the search phase, the OB provided a single interface through which participants could

save and organize passages, as well as document their thoughts. During the outline generation phase, the OB reduced the need to constantly shift their attention between multiple articles and the working outline. For example, P5 said *"I think it was helpful to get my thoughts all together in one place, one kind of screen."* Similarly, P7 said *"Based on my tab thing that I do, I'm constantly flipping back and forth between different pages and my Word document, which eats up a lot of time. And it's very distracting. [...] So for OrgBox, it was a way to just put it all in one section.*

Lastly, participants (n = 7) mentioned that the OB made it easier to *create* their outlines. For some participants, the visual and textual representations in the OB (i.e., groups, titles, hierarchies, passages, and notes) served as a type of draft version of an outline. For example, P11 stated *"Having everything organized at the end made writing the outline a lot easier. I really liked how organized it was. And that you could put different things under other things, a main point and then a sub-point, which is also how an outline works."*

Metacognitive activities: Participants described three main types of metacognitive activities supported by the OB: (1) planning, (2) monitoring, and (3) revising and updating. First, many participants (n = 10) mentioned that the OB caused them to think about the outline (the end goal) at an earlier stage, which also allowed them to guide their search accordingly. For instance, P15 said *"It helped me come up with a concrete plan for what I did want to do. I was able to map out what I wanted to learn or include in the outline."*

Second, several participants (n = 3) mentioned how the OB helped them monitor and assess their progress. The visual representations in the OB helped them identify knowledge gaps. Specifically, the number of boxes allowed participants to monitor the breadth of information gathered, while the number of passages in each box allowed them to monitor the depth. For example, P12 stated *"It helped me realize where I had like missing a dearth of information."* Similarly, P1 stated *"If I had a lot in one box and didn't have a lot in other boxes, it helped me realize, I need to go get more about a different portion of the topic."*

Lastly, many participants (n = 8) mentioned how they could revise and update their understanding of the topic by manipulating the representations in the OB. As they gathered information and learned more about a topic, they regrouped passages, refined labels, and reordered boxes to reflect changes in their understanding of the topic. They appreciated the fact that they could make such changes iteratively throughout the task (e.g., noting that nothing in the OB was *"set in stone."*). For instance, P12 said *"[being able to edit] was really helpful with the OrgBox because I would like, okay, this is sort of about this topic. Then I could change it or move it so that it wasn't locked into where I thought I was going to go with things [...] Just the fact that it was so iterative, I could go back and change things and fine-tune my thinking right there in real time [was helpful]."*

Leveraging information found serendipitously: Several participants (n = 3) mentioned that the OB allowed them to easily incorporate unexpected but relevant information encountered during their search. For instance, P7 reported finding passages that could form a sub-topic she had not thought of. With the OB, she was able to create a new box for those passages, set it aside, and easily switch back to the topic she was originally searching for.

Visual representation: Participants (n = 4) also appreciated being able to visually represent their ideas using the OB. The OB allowed participants to represent their understanding not only using text but also visually (by grouping and organizing spatially). The combination of the visual and textual representations of a topic was found particularly beneficial by so-called *"visual learners."*

4.3.2 Challenges of the OB. The OB also presented challenges and pitfalls, including: (1) usability, (2) forced externalization, (3) a lot of work, (4) feeling disoriented, and (5) mismatch between boxes and information found.

Usability: Participants (n = 6) mentioned having usability problems with the OB (e.g., boxes becoming invisible when placed partially outside the browser window).

Forced externalization: Participants (n = 4) mentioned having difficulties externalizing their thoughts using the OB. Specifically, they mentioned having difficulties creating boxes at the beginning of the task before getting a broad understanding of the topic. This was especially the case for those who prefer initiating the task by exploring the topic with no preconceived notions or plan. For instance, p4 said *"If I had read lots of things, bookmarked lots of things, and had time to process, then the OrgBox would have been helpful. But trying to do that from the outset [was difficult]."*

A lot of work: Participants (n = 5) mentioned the OB involving a lot of work in general. The OB required participants to engage in different cognitive activities (e.g., evaluating and organizing information) and physical activities (e.g., typing notes and positioning passages/boxes). Sometimes these activities "interrupted" each other, which made it difficult for some participants to stay focused and work quickly. For example, P7 stated *" If I found something and think, okay, this probably should be added to this section then I can scroll while I was dragging [...] I'd have to stop my train of thoughts to move it [box] out of the way."* Similarly, P10 stated *" I felt like I got slowed down by the process of organizing things and putting my notes. I think that slowed me down".*

Feeling disoriented: Participants (n = 3) mentioned feeling disoriented when interacting with the OB. This happened when participants had many ideas regarding what to search for (at the beginning) or when they found themselves with lots of information saved but unorganized in the OB (towards the end of the task). When participants failed to get a handle on their own representations of a topic, even with the OB, things were perceived to be unorganized and scattered. For instance, P5 said *"I feel like I knew what I wanted to research about. But then many ideas were coming into my head. Okay, I can research this, I can research this. I noticed at the end of the task, I was like I don't know how I'm going to structure my argument [...] I almost got tired. It was hard to see where everything was at [...] There wasn't any prioritizing in that moment."*

Mismatch between boxes and information found: Participants (n = 3) reported feeling concerned when they encountered potentially useful information that did not fit into any of the boxes created in the OB. Additionally, they felt frustrated when they did not find enough information to add to a box they created. For example, P10 stated *"I feel like I might have neglected other information that would have also been important [...] I didn't pull it out because it didn't go with one of the topics that I already picked."*

4.3.3 Benefits of the BK. The BK provided some benefits, including (1) lightweight function, (2) less work, and (3) initial push.

Lightweight function: Participants (n = 5) mentioned how simple and easy it was to use the BK. The functionality (drag-and-drop) as well as the purpose of the tool (saving passages in chronological order) was simple and straightforward.

Less work: Participants (n = 6) mentioned that the BK made the work easier because the tool itself required them to do hardly anything more than simply drag-and-drop. Whenever participants saw relevant information, they could instantly save it and move on. For instance, p12 said that it was nice that she could just *"grab stuff and didn't have to think about it much."* Similarly, P9 stated *"So from the perspective of finding information about something I already felt knowledgeable about, it was very efficient."*

Initial push: The BK did not support planning and strategizing (e.g., creating boxes), and it nudged participants to work in a linear fashion (i.e., one topic at a time). Interestingly, one participant (P5) found this helpful and stated *"[The BK] was really helpful in the sense that it forced me to go in a linear fashion. So, I had to figure out okay, this is what I want to first talk about, because that's going to get the very top [...] so it gave me that initial push."*

4.3.4 Challenges of the BK. The BK also presented a number of challenges and pitfalls, including: (1) difficulty remembering, (2) difficulty monitoring, (3) lack of guidance, (4) unable to organize, (5) a lot of "reconstruction" work, and (6) leaving information behind.

Difficulty remembering: Participants (n = 4) mentioned having difficulty remembering why they saved specific passages. For instance, P7 said *"Since there was no note or organization to it, I couldn't remember why I pulled out that specific quote."*

Difficulty monitoring: Participants (n = 4) mentioned having difficulty monitoring and assessing their progress, especially midway through the task when the BK list had gotten long. Specifically, they mentioned not being able to keep track of topics associated with saved passages and not being able to assess whether they had gathered enough information on certain topics.

Lack of guidance: Participants (n = 3) experienced a general lack of guidance while using the BK. Especially at the initiation phase, they had difficulty establishing a direction to pursue, which was related to the BK not supporting planning. For instance, p15 said *"Not knowing what direction I wanted to go in [was challenging]. It was really hard for me because I didn't have anything to write down what topics I might want to pursue."*

Unable to organize: As opposed to the OB, the BK did not allow participants to organize passages using visual and textual representations (e.g., boxes, hierarchies, titles, notes). Participants (n = 11) mentioned that the inability to organize information in the BK hindered their performance on the task. Some participants reported wanting to group passages and not being able to. For example, P12 stated *"there was no way to reorganize the stuff within and sort of group it like I would want to."* Additionally, the lack of organization made it difficult for participants to navigate the saved passages while creating the outline. For example, P15 said *"I think that made it a little more challenging. Just like the volume of information and the lack of any way to sift through it without just looking at it all night."* In terms of sensemaking, participants made comments about the BK list not being a meaningful representation. They perceived the BK list to be *"a stream of consciousness"* and *"a bunch of random information"*.

A lot of "reconstruction" work: Participants (n= 4) mentioned having to do a lot of work during the outline generation phase. First, they had to keep scrolling up and down in the list to locate specific information. Moreover, they needed to go through the list trying to "reconstruct" their motivations for saving certain passages and the logic behind the order of passages saved. Oftentimes, this required re-reading passages, re-associating passages with topics, and reconstructing the relationships between passages. For instance, P6 said *"Having to go back through the list with no indicators anywhere of what exactly it related to was a lot of work for the outline."*

Leaving information behind: In some cases, participants chronologically saved passages to the BK by topic. Participants (n=2) mentioned encountering a relevant passage but not saving it because it did not match the current topic. For example, P13 stated: *"I probably saw some things on the search engine that I wanted to add, but [...] it was just pointless for me to have something that I could have all the way at the top [...] (that I was going to talk about in the beginning of my outline) at the bottom."*

4.4 RQ4: Influences on Task Approach

RQ4 focuses on how the OB and BK tools influenced how participants approached the search task. In RQ4, we adopted a higher-level, *thematic* analysis approach, in which we interpret participants' descriptions and present three main themes that we observed: (1) the tool (OB vs. BK) influenced how participants *started* the task, (2) participants exhibited more purposeful, goal-oriented behaviors with the OB versus BK throughout the task, and (3) participants indicated wanting features from both tools.

Starting approach: Participants described how the specific tool (OB vs BK) influenced how they *started* the task. Participants discussed that the OB encouraged an approach where they had a "planning" phase prior to searching. These participants started the task by creating boxes first, and then searched to attempt to add information to the boxes. For instance, P8 said *"I had my three topics that I wanted to explore: Roe vs Wade, pro-choice, and anti-abortion or pro-life. I was able to label my boxes that way first. Created three boxes first then went to start searching, dropped it in making some notes, then moved on to the next one, the next one, and then went back in and manipulated each box a little bit to make sense and flow."* This approach worked especially well for participants with prior knowledge of the topic. However, even participants with little prior knowledge often used this type of planning phase with the OB to start a rough, malleable plan. Planning is one of the metacognitive activities that the OB was designed to support. Participants noted that the OB encouraged them to start thinking about the outline as they began the task. For instance, P15 said *"I just stepped back. I didn't search for anything to start with. I was just like, okay, If I were reading this [outline], what would I want to see out of it? [...] And then I made boxes for all of that."*

In contrast, participants described that the BK tool was suitable for searching and gathering information in a quick grab-and-go fashion, which can be helpful at the beginning of the task when the goal is just to get a broad sense of a topic. For example, P12 said *"It reminded me of how I used to do research like preliminary, just like the first pass, just taking a Word document and putting quotes and then the citation, and then later, I would go back and reorganize it [...] So, this was like that first part, just like okay, here's all the info."*

The OB encouraged goal-oriented behaviors: Participants described how the OB encouraged goal-oriented, "top-down" behaviors *throughout* their search process (not just at the start). This type of approach involved setting/revising goals and structures for the task and then engaging in search activities guided by these goals/structures. With the OB, participants were able to keep the structure visible, monitor it, and use it to guide their subsequent searches. For example, participants described classifying and labeling information found *while searching*, and performing searches specifically by noticing a box with little information (i.e., identifying a knowledge gap by reviewing the OB). In contrast, participants noted that the BK encouraged a "bottom-up" approach that involved starting out with a general search, saving information without thinking about its organization, and engaging in searches triggered by the information they encountered in a linear fashion.

Participants described using both top-down and bottom-up approaches in combination and how the OB supported smooth transitions between these. For instance, P7 started with two boxes representing opposing sides of the debate (top-down) and then added a box to represent new information she found while exploring the topic (bottom-up): *"I had made a section first of all that was saying there should be control of guns. Then I saw some articles that all had related things. So, I made a separate box that was something like a future step. Then I went back and started looking at specifically anti control."* Moving from bottom-up to top-down, P11 noted: *"Initially, I'm just kind of searching and finding all this data related to whatever. And I would title that and start putting things together. But as I did it, it helped me think through, this is how I might want to organize my paper, and so then I could edit the things there [...] I might edit the title of the box to reflect how I wanted to revise, refine it."*

Participants described how the BK tool was suitable for the bottom-up approach but did not provide features to support a top-down approach effectively. Thus, when using the BK, participants often described a bottom-up approach in which they gathered seemingly relevant information that they encountered along the way and then sorted and organized it in a later phase. For instance, P12 said *"It was just like, okay, I'm just gonna take that chunk of text and I'll deal with it later."* This approach may be beneficial when the goal is to get a broad understanding of a topic. However, this approach also *defers* the cognitive work of building structure (e.g., classifying, labeling, synthesizing) until after the search phase.

Participants wanted features from both the OB and BK: During the interviews, participants seemed to associate each tool with distinct purposes, based on the salient features of the tools. Furthermore, several participants said that they would like both tools available. We found these comments interesting because the OB could have been used in the same way as the BK. That is, participants could have created a "not yet organized" box in the OB to store interesting information that they did not yet have a dedicated box for. Interestingly, few participants adopted this approach, possibly because of their assumptions about how each tool *should* be used. Several participants said that they would like to have both tools and that they would use the BK first and then the OB. For instance, P4 said *"I would like them both if I were to write a paper. I would like to use bookmarking first and then organize in OrgBox, but I didn't like using the OrgBox by itself to search for information and organize immediately."* Additionally, P12 stated that *I would probably want to use the bookmark as a first step and then use the OrgBox when I had a better idea of what I was going to do.*

5 DISCUSSION

In this section, we discuss the main trends in our results.

Uses and Benefits of the OrgBox (RQ1-RQ3): Our RQ1 results (Figure 2) found that participants perceived the OrgBox (OB) to be more helpful than the Bookmark (BK) tool in supporting cognitive activities (organizing found information, drawing connections) and metacognitive activities (planning, monitoring progress, updating their approach). Our RQ2-RQ3 results provide insights into *how* features of the OB supported these activities and helped participants learn during the search task. In the paragraphs below, we discuss how the OB supported learning, cognitive, and metacognitive activities.

Learning—Participants noted that the OB helped them to identify important topics, recognize relationships between topics, and internalize information. In terms of important topics, participants mentioned that the OB helped them keep track of recurring themes (e.g., boxes with lots of information). In terms of recognizing relationships, participants reported classifying passages into boxes; using the notes feature to describe relations between passages; re-ordering passages within a box; forming hierarchies to express relations; positioning boxes to reflect how they planned to organize the outline; and recognizing that a passage could relate to multiple boxes. In terms of internalizing information, participants mentioned using the notes feature to summarize passages in their own words, to describe why the passage was helpful, and to describe how they intended to use the passage in the outline.

Cognitive activities—Participants noted how the OB helped them with organizing information, connecting ideas, and structuring the outline. Additionally, comments suggest that the OB helped participants with *switching* between different cognitive activities. During the search phase of the task, the OB helped participants explore topics in parallel (versus sequentially). This is important during complex tasks since articles often contain information about different aspects of a topic. Participants also mentioned that the OB helped them to incorporate information found *serendipitously* and then easily re-engage with their previous search process. For many participants, at the end of the search phase, their OB included boxes of topics, passages classified into topics, personal notes about passages, and hierarchies, all directly transferable to an outline.

Metacognitive activities—Participants described the OB as being helpful with metacognitive activities including monitoring and updating/revising. Monitoring is an important metacognitive activity that can support revising plans for subsequent searches [21]. Participants noted using the OB to monitor the breath and depth of information found by considering the number of boxes and the number of passages in each box, respectively. Often, this monitoring influenced their subsequent search activities.

Participants also described how the OB helped with metacognitive updating (i.e., changing/revising one's own knowledge structures based on new information). For example, as participants gathered more information, they sometimes refined the titles of their boxes to reflect their new understanding. As boxes evolved, participants moved passages between boxes. Throughout the search process, participants created/deleted boxes and changed their positions

(to restructure). These actions provide examples of participants externalizing the *changes* that occurred to their understanding of the topic. Vakkari [25] has argued that learning during search occurs when a searcher can engage in "restructuring" and "tuning" of knowledge structures through the use of new information (as our participants did using the OB tool).

Influences on Task Approach (RQ4): Our RQ4 results found that the OB/BK influenced how participants started the task and how they viewed their approach throughout task. We also found that participants wanted features of both tools (OB and BK).

Starting approach— The OB influenced participants to incorporate a planning phase at the beginning of the task. Many participants mentioned that the OB encouraged them to think first about the outline (the end goal) and thus, they began the task with a plan. Depending on their prior knowledge, this plan varied from a rough expectation (e.g., a box with a broad title) to a clear vision (e.g., multiple boxes with specific titles). In contrast, with the BK, participants mentioned that they *"just got started"* with little planning.

Task approach— We found evidence that the OB promoted goal-directed behaviors (i.e., a top-down approach) and also supported transitions between top-down and bottom-up approaches throughout the task. Participants mentioned that the information captured in the OB (e.g., box titles, what/how much is gathered for each box) helped them plan and guide their search towards their end goal. They also described situations where they: (1) started searching for a specific topic (top-down); (2) encountered information on another topic and created a box for it (bottom-up); and (3) resumed their original search (top-down). Conversely, the BK only supported a bottom-up approach. Participants worked in a "linear fashion" and could not build an external representation that could serve as a framework to guide their search process. Research has shown that both top-down and bottom-up approaches are critical for learning [14, 26]. Tools such as the OB that promote top-down approaches and transitions may help prevent searchers from "falling down a rabbit hole" or being distracted from the overarching goal.

The Best of Both Worlds– Participants mentioned wanting features of both the OB *and* the BK tools. For example, several participants commented that they would like to start their search using the BK tool and then switch to the OB after gathering some information. We found this to be an interesting comment since participants could have created a "catch-all" box in the OB that would have served a similar function to the BK tool (e.g., a box for things to "sort through later"). Our interpretation is that the design and interface of each tool may have conveyed assumptions to participants about how each tool *should* be used (e.g., based on their salient features). In this respect, the design of the OB may have failed to communicate that it could also be used in a way similar to the BK.

Participants' comments suggested that they viewed the BK as more suitable for searching and gathering information without planning or reflection. This approach may be effective when a searcher does not have much prior knowledge about the topic (e.g., at the beginning when the goal is to get a broad understanding of the topic). Conversely, the OB provided more support for planning and organizing while searching. Planning and organizing activities may be more effective once the scope of the task is established. This resonates with Kuhlthau's model of the information search process (ISP) [13], which suggests that people deal with vague thoughts and feelings of uncertainty until they define the scope of a task. Once the scope is defined, they enter a more focused mode of thinking and develop a sense of direction for the task. Thus, tools such as the BK may be useful during the pre-formulation stage and tools such as the OB may be more useful during the post-formulation stage, where targeted searching can occur. Crescenzi et al. [3] also found that complex note-taking structures (e.g., topical groupings) emerged as participants learned more about the task domain.

6 CONCLUSION

In this paper, we reported on a lab study that investigated the uses, benefits, and challenges of a novel tool (the OrgBox) designed to support users with complex search tasks. Our results have several important implications. From a methodological perspective, when evaluating tools, a common approach is to focus on post-task perceptions, such as workload and satisfaction. However, our RQ1-RQ4 results underscore the importance of considering *other* dimensions. Although we did not find any differences in participants' perceptions related to workload and satisfaction, we found significant differences in how the tool helped with cognitive and metacognitive activities (RQ1-RQ3). Moreover, our RQ4 results found that participants took distinctively different approaches to the task with different tools. Thus, we believe that future work should continue to consider such dimensions to better understand and evaluate how tools can support searchers with complex tasks.

Our results also have implications for designing systems to support users with complex search tasks. First, our results suggest that support tools should include features to spatially organize information and to make annotations, allowing searchers to create knowledge structures with both visual and textual cues. In our study, visual cues in the OrgBox (e.g., seeing a box with few passages) supported metacognitive activities such as monitoring and revising. Additionally, the visual and textual cues in the OrgBox played an important role during the outline generation phase, when participants had to re-engage with all the information saved. The organization in the OrgBox allowed participants to maintain a "big picture" perspective of a complex topic, re-find information, and remember the context in which information was saved. Second, with the OrgBox (vs. Bookmark), participants had an easier time generating a structured outline. Partly, this is because it influenced participants to think about the outline earlier in the task, plan their search, form groups of topics, and classify passages. This result suggests that support tools should influence searchers to engage with (and not postpone) the work activities that are *intrinsic* to the task. Third, participants reported wanting both tools, with the Bookmark at the start of the task. This highlights the nature of complex search tasks that involve various modes and stages of information seeking (e.g., pure exploration at the beginning and organizing/structuring throughout). Finally, and most importantly, our results provide insights about the types of cognitive and metacognitive activities involved in complex search tasks and *how* features of the OrgBox (e.g., visual and textual representations) supported these activities.

Acknowledgements: This research was supported by NSF grants IIS-1552587 and IIS-1451668. Any opinions, findings, conclusions, and recommendations expressed in this paper are those of the authors and do not necessarily reflect the views of the NSF.

REFERENCES

[1] Soonil Bae, Catherine C Marshall, Konstantinos Meintanis, Anna Zacchi, Haowei Hsieh, J Michael Moore, and Frank M Shipman. 2006. Patterns of reading and organizing information in document triage. *Proceedings of the American Society for Information Science and Technology* 43, 1 (2006), 1–27.

[2] John D. Bransford, Ann L. Brown, and Rodney R. Cocking. 2000. *How People Learn: Brain, Mind, Experience, and School: Expanded Edition.* The National Academies Press, Washington, DC.

[3] Anita Crescenzi, Yuan Li, Yinglong Zhang, and Rob Capra. 2019. Towards Better Support for Exploratory Search through an Investigation of Notes-to-Self and Notes-to-Share. In *Proceedings of the 42nd International ACM SIGIR Conference on Research and Development in Information Retrieval*. ACM, New York, NY, USA, 1093–1096.

[4] Bernhard Ertl. 2008. Computer Supported Collaborative Learning Scenarios: And External Representations for Promoting Them. In *Encyclopedia of Information Technology Curriculum Integration*. IGI Global, 138–143.

[5] John K Gilbert. 2005. Visualization: A metacognitive skill in science and science education. In *Visualization in science education*. Springer, 9–27.

[6] Lisa R Grimm. 2014. Psychology of knowledge representation. *Wiley Interdisciplinary Reviews: Cognitive Science* 5, 3 (2014), 261–270.

[7] Greg Guest, Emily Namey, and Mario Chen. 2020. A simple method to assess and report thematic saturation in qualitative research. *PLoS One* 15, 5 (2020), e0232076.

[8] Martin Halvey, David Vallet, David Hannah, and Joemon M. Jose. 2009. ViGOR: A Grouping Oriented Interface for Search and Retrieval in Video Libraries. In *Proceedings of the 9th ACM/IEEE-CS Joint Conference on Digital Libraries*. Association for Computing Machinery, New York, NY, USA, 87–96.

[9] Marti A. Hearst and Duane Degler. 2013. Sewing the Seams of Sensemaking: A Practical Interface for Tagging and Organizing Saved Search Results. In *Proceedings of the Symposium on Human-Computer Interaction and Information Retrieval (HCIR '13)*. Association for Computing Machinery, New York, NY, USA.

[10] Ken Hinckley, Shengdong Zhao, Raman Sarin, Patrick Baudisch, Edward Cutrell, Michael Shilman, and Desney Tan. 2007. InkSeine: In Situ Search for Active Note Taking. In *Proceedings of the SIGCHI Conference on Human Factors in Computing Systems (CHI '07)*. Association for Computing Machinery, New York, NY, USA, 251–260.

[11] Charles D. Holley and Donald F. Dansereau. 1984. CHAPTER 1 - The Development of Spatial Learning Strategies. In *Spatial Learning Strategies*. Academic Press, 3 – 19.

[12] David H. Jonassen, Katherine Beissner, Michael Yacci, and Katherine Beissner. 1993. *Structural Knowledge:Techniques for Representing, Conveying, and Acquiring Structural Knowledge*. Routledge.

[13] Carol Collier Kuhlthau. 2004. *Seeking meaning: A process approach to library and information services*. Vol. 2. Libraries Unlimited Westport, CT.

[14] Peter H Lindsay and Donald A Norman. 2013. *Human information processing: An introduction to psychology.* Academic press.

[15] Lindsay Mccardle and Allyson Hadwin. 2015. Using multiple, contextualized data sources to measure learners' perceptions of their self-regulated learning. *Metacognition and Learning* 10 (2015), 43—-75.

[16] Munehiro Nakazato, Ljubomir Manola, and Thomas Huang. 2003. ImageGrouper: A group-oriented user interface for content-based image retrieval and digital image arrangement. *Journal of Visual Languages & Computing* 14 (08 2003), 363–386.

[17] Joseph D. Novak, D. Bob Gowin, and Jane Butler Kahle. 1984. *Learning How to Learn.* Cambridge University Press.

[18] Daniel M. Russell, Mark J. Stefik, Peter Pirolli, and Stuart K. Card. 1993. The Cost Structure of Sensemaking. In *Proceedings of the INTERACT '93 and CHI '93 Conference on Human Factors in Computing Systems*. Association for Computing Machinery, New York, NY, USA, 269–276.

[19] Benjamin Saunders, Julius Sim, Tom Kingstone, Shula Baker, Jackie Waterfield, Bernadette Bartlam, Heather Burroughs, and Clare Jinks. 2018. Saturation in qualitative research: exploring its conceptualization and operationalization. *Quality & quantity* 52, 4 (2018), 1893–1907.

[20] Roger C Schank and Robert P Abelson. 2013. *Scripts, plans, goals, and understanding: An inquiry into human knowledge structures.* Psychology Press.

[21] Dale H Schunk and Barry J Zimmerman. 1994. *Self-regulation of learning and performance: Issues and educational applications.* Lawrence Erlbaum Associates, Inc.

[22] MJ Stefik, MQW Baldonado, D Bobrow, S Card, J Everett, G Lavendel, D Marimon, P Newman, DM Russell, and S Smoliar. 1999. The knowledge sharing challenge: The sensemaking white paper: PARC. (1999).

[23] Sigmar-Olaf Tergan. 2003. Managing knowledge with computer-based mapping tools. In *Proceedings of EdMedia + Innovate Learning 2003*, David Lassner and Carmel McNaught (Eds.). Association for the Advancement of Computing in Education (AACE), Honolulu, Hawaii, USA, 2514–2517.

[24] Sigmar-Olaf Tergan. 2005. *Digital Concept Maps for Managing Knowledge and Information.* Springer-Verlag, Berlin, Heidelberg, 185–204.

[25] Pertti Vakkari. 2016. Searching as learning: A systematization based on literature. *Journal of Information Science* 42, 1 (2016), 7–18.

[26] Stella Vosniadou and William F Brewer. 1987. Theories of knowledge restructuring in development. *Review of educational research* 57, 1 (1987), 51–67.

[27] Philip H. Winne and Roger Azevedo. 2014. *Metacognition* (2 ed.). Cambridge University Press, 63–87.

[28] William Wright, David Schroh, Pascale Proulx, Alex Skaburskis, and Brian Cort. 2006. The Sandbox for Analysis: Concepts and Methods. In *Proceedings of the SIGCHI Conference on Human Factors in Computing Systems*. Association for Computing Machinery, New York, NY, USA, 801–810.