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Search as Learning

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the essence of knowledge
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Search as Learning

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ABSTRACT

Search systems are often designed to support simple look-up tasks, such as fact-finding and navigation tasks. However, people increasingly use search engines to complete tasks that require deeper learning. In recent years, the search as learning (SAL) research community has argued that search systems should also be designed to support information-seeking tasks that involve complex learning as an important outcome. This monograph aims to provide a comprehensive review of prior research in search as learning and related areas.

Searching to learn can be characterized by specific learning objectives, strategies, and context. Therefore, we begin by reviewing research in education that has aimed at characterizing learning objectives, strategies, and context. Then, we review methods used in prior studies to measure learning during a search session. Here, we discuss two important recommendations for future work: (1) measuring learning retention and (2) measuring a learner's ability to transfer their new knowledge to a novel scenario. Following this, we discuss studies that have focused on understanding factors that influence learning during search and search behaviors that are

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predictive of learning. Next, we survey tools that have been developed to support learning during search. Searching for the purpose of learning is often a solitary activity. Research in self-regulated learning (SRL) aims to understand how people monitor and control their own learning. Therefore, we review existing models of SRL, methods to measure engagement with specific SRL processes, and tools to support effective SRL. We conclude by discussing potential areas for future research.

1

Introduction

For over a decade, researchers in the field of Search as Learning (SAL) have recognized that users frequently turn to search systems not only for simple fact-finding but to engage in complex learning tasks. This recognition has led to a growing body of work investigating how search systems can better support users in achieving complex learning outcomes. Over the years, researchers have explored many dimensions of SAL, including how learning objectives are defined in search contexts, the strategies learners use during search, and the factors that influence learning during information-seeking processes.

This monograph aims to highlight the significant progress made in SAL research, synthesizing key contributions while also framing future directions for this evolving field. Recent advancements, such as the integration of generative AI with search systems, underscore the need to revisit foundational theories and methodologies in light of new technologies. By reflecting on what has been accomplished and identifying gaps and opportunities, this monograph seeks to inspire future research and innovation in SAL. Addressing these research gaps will help to ensure that search systems are equipped to meet the ever-evolving demands of individuals by supporting their learning needs in a thoughtful, human-centered manner.

Learning theory is a vast and multidisciplinary field that includes a wide range of perspectives and approaches. This review focuses on specific sub-areas of learning theory, particularly those that have been most influential in shaping research and practice in SAL. While we highlight frameworks such as self-regulated learning (SRL) and tools like MetaTutor as exemplars, we also draw on foundational theories, including the Anderson & Krathwohl Taxonomy of Learning, constructivism, and the Zone of Proximal Development (ZPD), to frame our discussion. These frameworks and theories represent critical dimensions of how learning processes can be supported through search systems. However, we acknowledge that these perspectives are not exhaustive. Researchers engaging in SAL work are encouraged to explore relevant areas of the learning sciences that align with their study's theoretical lens and build on the foundational perspectives outlined in this monograph.

Additionally, while this monograph provides foundational perspectives to guide SAL research, it is important to acknowledge that it does not comprehensively connect all existing SAL research to the broader theories, frameworks, and empirical research from the learning sciences or other related fields. Given the breadth and complexity of these domains, this work emphasizes perspectives and connections most directly relevant to advancing SAL. This approach highlights opportunities for future researchers to explore novel connections between SAL and the wider landscape of learning sciences. Such efforts can enrich the field and inform the design of human-centered search systems that better support complex learning tasks.

In this section, we provide an overview of SAL. In particular, we discuss the foundations of SAL research and its primary objectives as established by researchers in the field. Next, we discuss concepts from developmental psychology and the learning sciences in which SAL is rooted, including constructivism, Vygotsky's Zone of Proximal Development (ZPD), and scaffolding. Then, we discuss the adjacent field of Intelligent Tutoring Systems (ITS) as this work is rooted in the same theory as SAL and shares similar objectives. Finally, we discuss exploratory search as it is a framework that centers learning and creating as important outcomes of information seeking.

1.1 Overview of Search as Learning (SAL)

Search systems are often designed, implemented, and evaluated as tools to help people find information. However, more than ever before, people use search systems to learn about a topic. For the most part, SAL research is concerned with scenarios in which a person interacts with a search system to fulfill a specific *learning objective*.

Key Takeaway

Search as Learning (SAL) explores how people interact with search systems to achieve their learning objectives.

A natural question is: What is a learning objective? Learning objectives have been characterized from different perspectives. One common characterization views learning objectives as having two main parts. First, a learning objective has a specific topic or domain. This can be called the *knowledge type* of the objective. Knowledge types can range from factual, to conceptual, to procedural knowledge. For example, imagine a searcher who wants to find the depth of the deepest part of the ocean. This searcher is aiming to gain factual knowledge. Imagine a searcher who wants to learn about the biological process of osmosis. This searcher is aiming to gain conceptual knowledge. Finally, imagine a searcher who wants to learn how to compute the area of a circle. This searcher is aiming to gain procedural knowledge.

Second, a learning objective has a specific *cognitive process*. The cognitive process of the objective defines the types of mental processes the learner wants to be able to engage in with the acquired knowledge. Cognitive processes vary by complexity. Perhaps a searcher simply wants to be able to recall the formula for computing the area of a circle. This is a simple objective that only requires rote memorization. Conversely, perhaps a searcher wants to understand why the area of a sphere is four times the area of a circle with the same radius. This is a more complex objective that requires understanding the relation between two procedures. In Section 2, we provide details on this characterization of learning objectives using the Anderson & Krathwohl Taxonomy of Learning (Anderson *et al.*, 2000).

Searching to fulfill a particular learning objective is an iterative process (Urgo and Arguello, 2022c) and can involve multiple sessions. During the search as learning process, searchers often interact with multiple sources, take notes, break the learning objective into smaller learning-oriented subgoals, and revisit topics to build on and check their own understanding. SAL research argues that searching for information not only involves finding answers but also acquiring new knowledge and understanding.

SAL research is multidimensional and considers a wide range of research questions. Some research might focus on understanding the real-world contexts in which people search for the purpose of learning. Other research might focus on better understanding the SAL process. That is, what do people do when they search for the purpose of learning? Other research might focus on developing tools to encourage and support learning during search. Research might also focus on discovering search behaviors that predict learning during search. Finally, SAL research might have a more methodological aim. For example, how might we analyze an artifact like an essay produced after the search session in order to measure learning?

1.2 Early Calls for SAL Research

Learning has been a subject of research in information retrieval (IR) for many years. Three meetings were central to the establishment of the SAL research community: The Second Strategic Workshop on Information Retrieval in Lorne (SWIRL) (Allan *et al.*, 2012), Dagstuhl Seminar 13441 (Agosti *et al.*, 2014), and Dagstuhl Seminar 17092 (Collins-Thompson *et al.*, 2017).

In 2012, the three-day SWIRL workshop emphasized the importance of supporting searching and learning as one of many emerging topics. In 2013, Dagstuhl Seminar 13441 included a working group that focused on "From Searching to Learning." Topics discussed included behaviors that are correlated with learning during search and ways to measure learning during search. Subsequently in 2017, Dagstuhl Seminar 17092 was entirely dedicated to SAL. Discussions from the seminar established four main areas for future research: (1) examining search as a learning process; (2) measuring learning performance and outcomes during search; (3) investigating the contexts in which people search to learn; and (4) developing search tools and interventions to promote learning.

In addition to these workshops, two conference workshops (Freund *et al.*, 2014; Gwizdka *et al.*, 2016), an ASIST panel (Rieh *et al.*, 2014), and two special journal issues focused on SAL (Hansen and Rieh, 2016; Eickhoff *et al.*, 2017).

1.3 Related Topics and Fields

SAL research aims to develop search environments that encourage and support learning. To this end, we must grapple with a few fundamental questions. How do people learn? What is an individual capable of learning at a given point in time? What is the best way for a system to encourage and support learning? SAL researchers are not the first to think about these questions. The SAL research community has pulled from a variety of theories and frameworks established in psychology and education. In this section, we provide an overview of three important concepts: constructivism, the zone of proximal development (ZPD), and scaffolding.

Constructivism is a theory of how people learn. Learning requires an individual to integrate new information into their existing knowledge structures. In this respect, learning requires an individual to be an *active* participant in their own learning process. SAL research is concerned with scenarios in which individuals learn by actively interacting with information using a search system. Therefore, a constructivist perspective on learning is central to SAL research.

The concepts of ZPD and scaffolding go hand in hand. Helping searchers learn begs the question: What can someone learn completely unaided and what can someone learn with some guidance? The ZPD is defined as the range of things an individual might be able to learn with some guidance from a more knowledgeable peer or system. Scaffolding is defined as instructional interventions that support learning while still letting the learner "figure it out on their own." Systems that provide scaffolding adopt a constructivist perspective on learning (i.e., supporting learners in actively constructing their own understanding rather than passively receiving information).

In this section, we also discuss two related research areas: intelligent tutoring systems (ITS) and exploratory search. Research in ITS aims to develop non-search, computer-based systems that help people learn. Exploratory search considers search tasks that involve learning and creativity as important outcomes.

1.3.1 Constructivism

How do people learn? Introduced by Jean Piaget (Piaget and Cook, 1952), the theory of constructivism argues that individuals learn through experiences and social interaction, and by integrating new information with their existing knowledge. That is, individuals are not empty vessels that acquire knowledge only through absorption during direct instruction. Instead, learning requires an individual to engage with new material and integrate it into their existing knowledge. In this respect, constructivism indicates that learners must be active participants in their own learning process. For example, someone is likely to learn about a procedure more deeply by using the procedure to solve a problem rather than simply memorizing and reciting the steps.

Key Takeaway

Constructivism asserts that meaningful learning occurs when learners actively engage in experiences, enabling them to integrate new knowledge into their existing understanding.

The theory of constructivism argues that people learn through the processes of assimilation and accommodation (Piaget and Cook, 1952; Hanfstingl *et al.*, 2021). Assimilation is the process of taking new information and fitting it into an existing schema. Sometimes, the new information does not fit neatly into an existing schema. Therefore, accommodation is the process of using newly acquired information to revise or redevelop the existing schema, resulting in a more accurate and/or complete schema. Constructivism argues that learning is not a passive activity. People cannot learn by simply "taking in information." They must reflect on it, link it to what they already know, and create new knowledge structures when necessary. Therefore, people learn more when they are active participants in their own learning. Learners that participate in the active construction of their own knowledge gain a deeper understanding, are more able to generalize beyond the learning context, and have higher levels of motivation (Sawyer, 2014).

For decades, much research in information retrieval has adopted a constructivist approach. Talja *et al.* (2005, p. 83) describe the constructivist perspective of the user in information science: "An information user is not a passive information processing system but actively makes sense of the surrounding reality and attaches personal meanings to information."

Within SAL, Eickhoff *et al.* (2017, p. 399) underscored the important role of constructivism in advancing future search system design: "knowledge is derived from personal experience and ideas rather than an aggregation of loose facts and formulas." They also emphasize that: "Despite the wide acceptance and demonstrated success of constructivist methods in pedagogy, common retrieval models do not explicitly manifest any notion of *contextual learning*" (Eickhoff *et al.*, 2017, p. 399).

Constructivism emphasizes that learning occurs when people actively construct knowledge by integrating new information with their existing understanding. However, current search systems are not designed to support these fundamental learning processes of assimilation (i.e., fitting new information into an existing knowledge schema) and accommodation (i.e., adapting or revising a knowledge schema to fit new information). While search engines excel at retrieving relevant information, they do not help learners connect new discoveries with their prior knowledge, nor do they encourage the active engagement necessary for meaningful learning. Search results are typically presented as isolated pieces of information rather than as building blocks that can be integrated into a learner's existing knowledge structure. To support learning, search systems might be designed instead to facilitate active knowledge construction by helping learners connect information to their existing understanding.

1.3.2 Vygostky's Zone of Proximal Development (ZPD)

Vygotsky and Kozulin (1962) introduced the notion of *social constructivism*, which emphasized the importance of social learning through models such as parents or peers. Shown in Figure 1.1, Vygotsky's *Zone of Proximal Development* (ZPD) is a model that positions learning stages into three categories: (1) that which the student can learn on their own; (2) that which the student can learn given assistance from a more knowledgeable peer or mentor; (3) and that which the student is not yet able to learn even with help (Vygotsky, 1980).

The ZPD represents the optimal space for learning, between what learners cannot yet understand and what they are already able to understand on their own. Current search systems, however, present information without consideration for where it falls within a learner's ZPD. However, prior work in SAL has aimed to explore ways in which we can improve upon these existing systems. Smith *et al.* (2022) demonstrate how knowledge graph coverage could be used to infer a learner's ZPD, allowing systems to identify content that is neither too basic nor too advanced for individual learners. Such a system could potentially enhance learning outcomes by ensuring that search results align with a learner's current capabilities and their potential for growth.

In information seeking research, Kuhlthau (1994) models the zone of intervention on the ZPD. The zone of intervention underscores the need for a more knowledgeable peer or instructor to select the appropriate intervention for the individual at the appropriate moment during the information-seeking process. Mechanisms put in place during such an intervention are often known as *scaffolding*.

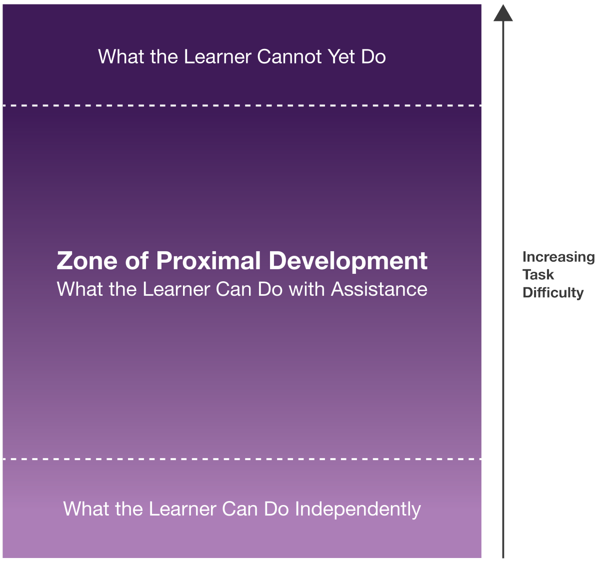

Figure 1.1: Vygotsky's Zone of Proximal Development (adapted from Vygotsky, 1980).

1.3.3 Scaffolding

Scaffolding, as the metaphorical term implies, are mechanisms of support provided by an instructor which are gradually removed or faded as higher levels of cognitive understanding are achieved. Scaffolding is help that is tailored to the learner's needs in order to achieve their goals (Sawyer, 2014).

Key Takeaway

Scaffolding are supports provided by an instructor to facilitate learning that are gradually removed or faded as understanding is achieved.

While simply giving a learner an answer will help them achieve their goal quickly, scaffolding is applied for effective long-term learning. Scaffolding takes a constructivist approach to learning. Good scaffolding provides hints and prompts that help the learner figure things out on their own (Sawyer, 2014). That is, good scaffolding keeps the learner as an active participant in their own learning.

As shown in Table 1.1, Mariani (1997) characterizes effective scaffolding through the dimensions of challenge and support. Ideally, scaffolding is both *high* challenge and *high* support. The other three combinations are likely to lead to suboptimal outcomes. If both challenge and support are low, the learner may become bored and unmotivated. If challenge is high but support is low, the learner may become frustrated and anxious. Finally, if challenge is low but support is high, the learner might feel that they are doing "busy work" and getting little out of the exercise. The best combination, high challenge and high support, is most likely to result in greater engagement, improvements in self-confidence, and better learning outcomes.

Table 1.1: Benefits of High Challenge and High Support Scaffolding (adapted from Mariani, 1997).

	Challenge	
Support	**Low**	**High**
Low	• Low motivation • Boredom • Apathy	• Low self-confidence • High anxiety • Frustration • Failure likely
High	• Low learning • Comfortable • Busy work • Dumbing down	• High learning • High engagement • High self-confidence • Extension of capability

Scaffolding has traditionally referred to the support provided by a teacher or more knowledgeable peer. More recently, a large body of work has broadened scaffolding to include support that is provided by tools, resources, and environments (Sharma and Hannafin, 2007). These tools and resources demonstrate relevant aspects of a task or provide strategies in achieving a learning objective. In particular, such scaffolding has been instantiated in computer-based or technology-enhanced learning environments. These environments implement scaffolding in different ways, for example by: (1) helping the learner understand the landscape of a complex task or domain; (2) visualizing and modeling complex scientific phenomena; and (3) providing interactive guidance and support (Puntambekar and Hübscher, 2005).

While there are clear benefits of using computer-based scaffolding for learning (Belland *et al.*, 2017), Puntambekar and Hübscher (2005) argue that much of the prior work in this area has used a broad application of the term scaffolding that has led to certain shortcomings. Technology-enhanced or computer-based learning tools typically provide passive support. This means that learners do not benefit from the dynamic or adaptive scaffolding that can be provided from a one-on-one teacher. Most often these tools employ blanket supports that are the same for all learners.

Fading (i.e., gradually decreasing scaffolding (McNeill *et al.*, 2006)) is an important and mostly overlooked component of scaffolding by computer-based tools. Typically, support is ongoing and unchanging. Without fading support, learners do not benefit from intermittent self-evaluation of distinguishing what they can and cannot do without support. Current search systems often provide static interfaces and functionality regardless of a user's evolving capabilities and needs. This non-contextualized approach fails to provide the adaptive scaffolding necessary for meaningful learning.

1.3.4 Intelligent Tutoring Systems (ITS)

Individual tutoring is an important method for teaching and learning that researchers have attempted to emulate from the earliest years of computing (Smith and Sherwood, 1976). Intelligent tutoring systems (ITS) have existed for decades. Corbett *et al.* (1997) recognize the first intelligent tutoring program to be SCHOLAR (Carbonell, 1970) from 1970.

There are two categories of ITS: step-based and substep-based. Step-based systems (Kim *et al.*, 1989; Woo *et al.*, 2006) allow learners to enter the steps of their problem-solving process without a tutoring intervention. Substep-based systems (Evens *et al.*, 1997) provide scaffolding and feedback at a finer level of detail than the learners' problem-solving steps. The primary difference between step-based and substep-based systems is that substep-based systems engage learners in a dialogue in order to better understand their reasoning (e.g., ask a learner *why* they made a particular decision) and potentially correct errors at a deeper level of understanding.

The origin of cognitive tutors is rooted in work by Anderson *et al.* (1985), who designed an ITS aimed at supporting the acquisition of cognitive skills, which they define as units of goal-related knowledge. Aleven *et al.* (2006, p. 102) introduced the term Cognitive Tutor as a type of ITS that "is designed to support *learning by doing* and features a cognitive model of the targeted skills, expressed as production rules." The cognitive models integrated into a cognitive tutor represent a learner's thinking in a particular domain and include early learner strategies and misconceptions common to the path from novice to expert. Built on top of these cognitive models are rich graphical problem-solving environments, the combination of which are designed to support individual learning.

1.3.5 ITS Integration of Constructivism, ZPD, and Scaffolding

MetaTutor was developed by Azevedo *et al.* (2009) and differs from other cognitive tutors because it is both an ITS *and* hypermedia learning environment. While cognitive tutors were designed specifically for learning procedural knowledge (using production rules or proof logic formalism), MetaTutor is focused on teaching conceptual knowledge, specifically complex biological processes (e.g., knowledge about circulatory, digestive, and nervous systems) (Azevedo *et al.*, 2009; Azevedo *et al.*, 2012).

In Section 7, we focus on MetaTutor as an example to demonstrate how the foundations of constructivism, Vygotsky's ZPD, and scaffolding have been successfully integrated into learning systems outside of SAL. MetaTutor is also rooted in self-regulated learning (SRL) theory and aims to support SRL processes, which is the focus of Section 7.

1.3.6 Exploratory Search

In the early 2000's, IR researchers recognized that people use search systems for more than simple lookup tasks. However, search systems were inadequate when faced with these types of user demands that included analysis, decision making, and learning about a new topic. Recognizing these emerging needs and expectations of users, Marchionini introduced exploratory search (Marchionini, 2006).

Marchionini identified three large categories of search processes: lookup, learn, and investigate. Lookup processes include fact-finding and verifying—gathering information about who, when, and where. In contrast, exploratory search answers questions related to what, how, and why. Exploratory search involves processes such as learning (e.g., knowledge acquisition, comparison, and integration) and investigating (e.g., analysis, evaluation, and synthesis).

Particularly relevant to the roots of SAL, Marchionini describes *learning searches* as part of exploratory search. Learning searches involve multiple search iterations, sifting through various types of media, complex cognitive processing, and comparing and judging information. Learning searches are rooted not only in traditional academics, but also in general lifelong and professional learning.

Key Takeaway

Learning searches involve multiple search iterations, multiple types of media, and complex cognitive processing like comparing and judging information

Investigation searches involve multiple iterations over an extended period. Investigative searchers are more critical of information before it is integrated into their existing knowledge structures. Like learning searches, investigation searches are also learning-oriented. However, they involve cognitive processes that are highly complex (e.g., analysis, evaluation, and synthesis). Investigative searchers aim to discover gaps in knowledge, create future plans, and transform existing information into a new framework or form.

1.4 Related Surveys

There have been several existing surveys that aim to better position and unify the SAL research agenda.

Rieh *et al.* (2016) position SAL research across three main categories: (1) studies that explore search behavior in learning environments; (2) studies aimed at improving the search skills of students; and (3) studies aimed at developing search environments that improve learning outcomes and experiences. Most SAL studies are motivated (directly or indirectly) by the vision of search systems that better support learning.

The International Workshop on Investigating Learning during Web Search (IWILDS) has been held for several years (Hoppe *et al.*, 2020; Hoppe *et al.*, 2021; Hoppe *et al.*, 2022). Topics presented at the workshop have included search algorithms to improve learning, as well as methods for capturing self-regulated learning (SRL) processes during a SAL study.

von Hoyer *et al.* (2022b) propose the so-called "spaceship" model of SAL. The end goal was to provide a vision of SAL that brings together ideas from information retrieval, education, and psychology. In particular, the model contains several key components: (1) the learner's context; (2) the learner; (3) the interface; (4) the IR backend; and (5) the collection of online resources. The model emphasizes the importance of self-regulated learning (SRL) in SAL. von Hoyer *et al.* (2022b) highlight the need for search systems to better support metacognitive monitoring and metacognitive control while learning during search.

Smith *et al.* (2022) envisioned a multi-component search environment to help students learn in the context of a school assignment. The framework involves modules that model the topical domain, the assignment, the learner's existing state of knowledge, the learner's past search behaviors and learning strategies, and the document corpus. These modules dynamically update each other when new evidence becomes available and influence the retrieval model so that the learner can engage with information that is relevant to the assignment, novel, and at the right level of complexity given their existing knowledge state.

Both proposed frameworks from von Hoyer *et al.* (2022b) and Smith *et al.* (2022) highlight the importance of SRL, the learner's context, and the dynamic adaptation of the search environment based on a learner's goals and progress.

1.5 Outline

In the sections that follow, we survey prior work relevant to SAL and propose directions for future research.

Section 2: SAL research is concerned with scenarios in which a user interacts with a search system to achieve a specific learning objective. Therefore, an important question is: How do learning objectives vary? In Section 2, we explore how learning objectives have been characterized in prior work. Much of this work originates from the field of education. Education researchers have proposed different taxonomies to define learning objectives. These taxonomies were developed to help teachers more clearly define learning objectives for students and to ensure that instructional activities and assessment methods align with the objectives. For example, if a teacher wants their students to be able to do XYZ, then the instructional activities should align with this goal. Similarly, to determine whether the instructional activities were successful, the learning assessment should test the students' ability to do XYZ. SAL researchers have leveraged these taxonomies of learning to systematically manipulate learning-oriented search tasks and to study the effects of those manipulations on different types of outcomes (e.g., behaviors, perceptions, challenges, etc.).

Section 3: SAL studies rely on measuring how much someone learned during a search session. As it turns out, there are many ways to do this. In Section 3, we review the different learning assessment methods that have been used in prior work. Importantly, we discuss the benefits and drawbacks of each method. To illustrate, multiple-choice assessments are easy to grade but may not capture everything someone learned. On the other hand, open-ended assessments—asking participants to describe what they learned—have a broader scope but can be difficult to grade. Additionally, we detail how past work has accounted for prior knowledge in order to measure knowledge *gains* during a search session. Finally, we propose directions for future work. For example, we argue that future work should consider knowledge retention (i.e., being able to use what was learned in the long term) and transfer of learning (i.e., being able to apply what was learned in a new context).

Section 4: SAL studies have explored how different factors may impact learning during search. In Section 4, we survey prior work that has investigated factors related to: (1) the search task or learning objective and (2) the individual searcher. With respect to the search task, most work has focused on the complexity of the task. With respect to the individual searcher, studies have focused on prior knowledge and specific cognitive abilities, such as working memory capacity, perceptual speed, and an individual's tendency to become distracted while working on a task.

Section 5: SAL researchers are interested in developing search environments that encourage and support learning. Therefore, an important question is: How can we *automatically* determine whether an existing system is helping users learn? In Section 5, we survey studies that have investigated whether and how specific search behaviors can predict learning during search. The idea is to predict learning using measures that can be easily logged by a search system.

Section 6: In Section 6, we survey SAL studies that have explored how different system features and tools can support learning during search. For example, studies have considered features of the search interface (e.g., visualizing the coverage of subtopics throughout the search session), as well as peripheral tools for annotating documents or taking notes.

Section 7: When someone searches to learn, they are in control of their learning process. That is, there is no human tutor instructing the searcher on what to do, when, and how. In education and the learning sciences, self-regulated learning (SRL) is a field of study that examines how people learn on their own. It examines the types of mental processes that lead to successfully achieving learning goals. SRL processes include setting goals, enacting effective strategies to achieve the goals, monitoring progress toward the goals, and making adjustments when necessary. In Section 7, we introduce SRL, describe different SRL models that have been proposed, and delve deeply into the Winne and Hadwin model of SRL (Winne and Hadwin, 1998). Goal-setting is a critical phase of the SRL process. Therefore, we also review prior work on the effects of goal-setting on learning and on the characteristics of goals that improve performance. Finally, we describe methods for capturing SRL processes during search. We argue that SAL researchers should more carefully study SRL processes during search and think about ways to support effective SRL toward meaningful learning.

Section 8: Finally, in Section 8, we propose future directions for SAL research. We discuss eight general areas for future work to consider: (1) transfer of learning, (2) designing context-aware SAL environments, (3) investigating long-term SAL processes through longitudinal research, (4) self-determined learning, (5) learning within highly debated topics, (6) scaffolding to encourage and support self-regulated learning (SRL) processes, (7) leveraging generative AI technologies to develop new features to help searchers learn, and (8) studying how groups of individuals learn together.

In this monograph, the tone shifts from descriptive to persuasive in certain sections to align with their distinct purposes. In Section 7 on SRL, the persuasive tone is grounded in two key considerations. First, a large body of empirical evidence from the learning sciences demonstrates that effective SRL significantly improves learning outcomes. Second, despite these established findings, SRL has not been adequately integrated into the theoretical frameworks or methodologies used in SAL research, representing a critical area of opportunity.

Similarly, the tonal shift in Section 8 on future directions reflects our intent not only to synthesize and lay a foundation of what has been done, but also to advocate for and highlight pressing gaps and research needs. While this monograph does not claim to cover all possible directions, it emphasizes those the collective research community has identified as impactful through existing work, aiming to inform and inspire future research in the field.

1.6 Target Audience and Reading Tips

Who is this monograph intended for? There are several audiences that may benefit. Certainly, we intended this monograph to be useful for information retrieval (IR) researchers who are *new* to SAL research. For example, a graduate student looking for a research topic related to SAL should benefit from learning about what has been done and what open questions remain.

Additionally, researchers *already* conducting SAL research should also benefit. For example, several sections may benefit a researcher planning a SAL study. Section 2 may provide ideas on how to systematically manipulate learning-oriented search tasks assigned to participants. Section 3 may provide ideas about how to measure learning during search. Section 6 and Section 7 may provide ideas about novel tools to support learning during search. Specifically, Section 7 may provide ideas about tools to both encourage and support self-regulated learning (SRL) processes that have been empirically shown to improve learning.

Finally, we also intended the monograph to be useful and interesting for researchers *outside* of IR. Researchers in education and cognitive science may find it interesting to see how IR researchers have investigated learning during search. SAL research is inherently multidisciplinary. We hope for this monograph to grab the attention of non-IR researchers. Multiple voices and perspectives may help SAL researchers avoid "reinventing the wheel", employ the best methods, and pursue the most impactful research directions.

Another important question is: What is the best way to read this monograph? We intentionally wrote each section to be self-contained. For example, the same study may be referenced in different sections for different reasons. Section 2 may discuss how the study manipulated learning objectives, Section 3 may discuss how the study measured learning, and Section 6 may describe the novel tools that were used to support learning during search. Therefore, we encourage readers to focus on those sections most interesting to them.

Finally, some readers may find some sections to be written in greater detail than others. For example, Section 7 describes prior research in SRL in great detail. This was done intentionally, as we believe that supporting effective SRL is an exciting area for future SAL research to consider.

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