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LongSAL: A Longitudinal Search as Learning Study With University Students [Draft]

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by

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Abstract

LongSAL: A Longitudinal Search as Learning Study With University Students [Draft]

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The University of Texas at Austin, 2023

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Learning today is about navigation, discernment, induction, and synthesis of the wide body of information on the Internet present ubiquitously at every student's fingertips. Learning, or addressing a gap in one's knowledge, has been well established as an important motivator behind information-seeking activities. The Search as Learning research community advocates that online information search systems should be reconfigured to become educational platforms to foster learning and sensemaking. Modern search systems have yet to adapt to support this function. An important step to foster learning during online search is to identify behavioural patterns that distinguish searchers gaining more vs. less knowledge during search. Previous efforts have primarily studied searchers in the short term, typically during a single lab session. Many researchers have expressed their concern over this ephemeral approach, as learning takes place over time, and is not fleeting. We propose an exploratory longitudinal study to analyze the long-term searching behaviour of students enrolled in a university course, over the span of a university semester. Our research aims are to identify if and how students' searching behaviour changes over time, as they gain new knowledge on a subject; and how do processes like motivation, metacognition, self-regulation, and other individual differences moderate their 'searching as learning' behaviour. Findings from this exploratory longitudinal study will help to build improved search systems that foster human learning and sensemaking, and are more

equitable in the face of learner diversity.

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1 Introduction

1.1 Searching as Learning: Overview

Searching for information is a fundamental human activity. In the modern world, it is frequently conducted by users interacting with online search systems (e.g., web search engines), or more formally, **Information Retrieval** (IR) systems. As early as in 1980, Bertam Brookes, in his 'fundamental equation' of information and knowledge, had stated that an information searcher's current state of knowledge is changed to a new knowledge structure by exposure to information (Brookes, 1980, p. 131). This indicates that searchers acquire new knowledge in the search process, and the same information will have different effects on different searchers' knowledge states. Fifteen years later, Marchionini (1995) described information seeking as "a process, in which humans purposefully engage in order to change their state of knowledge". Thus, we have known for quite a while that search is driven by higher-level human needs, and IR systems are a means to an end, and not the end in itself. **Interactive information retrieval** (IIR), a.k.a. human-computer information retrieval (HCIR) (Marchionini, 2006) refers to the study and evaluation of users' interaction with IR systems and users' satisfaction with the retrieved information (Borlund, 2013).

Despite their technological marvels, modern IR systems falls short in several aspects of fully satisfying the higher level human need for information. In essence, IR systems are software that take, as input, some query, and return as output some ranked list of resources.

> *Within the context of information seeking, (search engines and IR systems)* ***feel*** *like they play a prominent role in our lives, when in actuality, they only play a small role: the* ***retrieval*** *part of information . . .*
>
> - *Search engines* ***don't help us identify what we need*** *– that's up to us; search engines don't question what we ask for, though they do recommend queries that use similar words.*
> - *Search engines* ***don't help us choose a source*** *– though they are themselves a source, and a heavily marketed one, so we are certainly compelled to choose search engines over other sources, even when other sources might have better information.*
> - *Search engines* ***don't help us express our query*** *accurately or precisely – though they will help with minor spelling corrections.*
> - *Search engines do help retrieve information—this is the primary part that they automate.*
> - *Search engines* ***don't help us evaluate the answers we retrieve*** *– it's up to us to decide whether the results are relevant, credible, true; Google doesn't view those as their responsibility.*
> - *Search engines* ***don't help us sensemake*** *– we have to use our minds to integrate what we've found into our knowledge.*
>
> — Ko (2021)

In recent years, the IIR research community has been actively promoting the **Search as Learning** (SAL) research direction. This fast-growing community of researchers propose that search environments should be augmented and reconfigured to foster learning, sensemaking, and long-term knowledge-gain. Various workshops and seminars have been organized to develop research agendas at the interaction of IIR and the Learning Sciences (Agosti et al., 2014; Allan et al., 2012; Collins-Thompson et al., 2017; Freund et al., 2013, 2014; Gwizdka et al., 2016). Additionally, special issues on Search as Learning have also been published in the *Journal of Information Science* (Hansen & Rieh, 2016) and in the *Information Retrieval Journal* (Eickhoff et al., 2017). Articles in these special issued presented landmark literature reviews (Rieh et al., 2016; Vakkari, 2016), research agendas, and ideas in this direction. Overall, these works generally advocate that future research in this domain should aim to:

- understand the contexts in which people search to learn
- understand factors that can influence learning outcomes
- understand how search behaviours can predict learning outcomes
- develop search systems to better support learning and sensemaking
- help searchers be more critical consumers of information
- understand the cognitive biases fostered by existing search systems
- develop search engine ranking algorithms and interface tools that foster long term knowledge gain

Parallelly, the Educational Science and the Learning Science research communities have also been organizing workshops and formulating research agendas to conceptualize forms of 'new learning' (Cope & Kalantzis, 2013; Kalantzis & Cope, 2012; New London Group, 1996) that are afforded by innovations in digital technologies and e-learning ecologies (Cope & Kalantzis, 2017). Higher education researchers have been increasingly studying how students' information search and information use behaviour affect and support their learning (Weber et al., 2018, 2019; Zlatkin-Troitschanskaia et al., 2021). Efforts are underway to conceptualize a theoretical framework around new forms of e-Learning that is aided and afforded by digital technologies (Amina, 2017; Cope & Kalantzis, 2017). In the community's own words: "learning today is more about navigation, discernment, induction, and synthesis" of the wide body of information present ubiquitously at every student's fingertips (Amina, 2017). Therefore, "knowing the source, finding the source, and using the information aptly is important to learn and know now more than ever before" (Cope & Kalantzis, 2013). All of these interests in the intersection of searching and learning goes to emphasize that understanding learning during search is critical to improve human-information interaction.

1.2 Problem Statement

A major limitation in the area of Search as Learning, Interactive IR (IIR), and more broadly, in Human-Computer Interaction (HCI) research is that, the user is examined in the short-term, typically over the course of a single experimental session in a lab (Karapanos et al., 2021; Kelly et al., 2009; Koeman, 2020; Zlatkin-Troitschanskaia et al., 2021). Very few studies exist in the search-as-learning domain that have observed *the same participant* over a longer period of time than a single search session (Kelly, 2006a, 2006b; Kuhlthau, 2004; Vakkari, 2001; White et al., 2009; Wildemuth, 2004). This ephemeral approach has acute implications in any domain where learning is involved because "learning is a *process* that leads to *change* in knowledge ... (which) unfolds over time" (Ambrose et al., 2010), and "... does not happen all at once" (White, 2016b).

To the best of the author's knowledge, almost no new longitudinal studies were reported in major search-as-learning literature in the last five years, that systematically studied students' information search behaviour and information-use over the long term, in their *in-situ* naturalistic environment and contexts, and linked those behaviours quantitatively to the students' learning outcomes and individual differences.

Higher education students are increasingly using the Internet as their main learning environment and source of information when studying. Yet, the short term nature of research in this domain creates significant gaps in our knowledge regarding how students' information search behaviour and information use develop over time, and how it affects their learning (Zlatkin-Troitschanskaia et al., 2021).

> *When research in this area relies so heavily on (short-term) lab studies, can we realistically say we are comprehensively studying human-tech interactions – when many of those interactions take place over long periods of time in real-world contexts? ... An over-reliance on short studies risks inaccurate findings, potentially resulting in prematurely embracing or disregarding new concepts.*
>
> — Koeman (2020)

Current search engines and information retrieval systems "do not help us know what we want to know, ...do not help us know if what we've found is relevant or true; and they do not help us make sense of the retrieved information. All they do is quickly retrieve what other people on the internet have shared" (Ko, 2021). Unless we have more long-term understanding of the nature of knowledge gain during search, the limitations of current search systems will continue to persist. Increased knowledge and understanding of students', and more broadly searchers', information searching and learning behaviour over time will help us to overcome the limitations of current IR systems, and transform them into rich learning spaces where "search experiences and learning experiences are intertwined and even synergized" (Rieh, 2020). The internet and digital educational technologies offer great opportunities to transform learning and the education experience. Enabled by our increased comprehension of the longitudinal searching-as-learning process, improved and validated by empirical data, we can create a new wave of fundamentally transformative educational technologies and "e-learning ecologies, that will be more engaging for learners, more effective (than traditional classroom practices), more resource efficient, and more equitable in the face of learner diversity" (Cope & Kalantzis, 2017).

1.3 Purpose of this Dissertation Proposal

To address the gaps in our knowledge of how information searching influences students' learning process over time, this dissertation proposal proposes to conduct a semester-long longitudinal study (approx. 16 weeks) with university student participants. The overarching research aim is to identify how students' online searching behaviour correlate with their learning outcomes for a particular university course. Building upon principles from the Learning Sciences (Ambrose et al., 2010; National Research Council, 2000; Novak, 2010; Sawyer, 2005), and empirical evidences from the Information Sciences (Rieh et al., 2016; Vakkari, 2016; White, 2016a), this dissertation proposal aims to:

- situate students as learners in their naturalistic contexts, and characterized by their individual differences

- measure students' information search and information use behaviour over time
- correlate the information search behaviour with the learning outcomes for the university course

Learning, or addressing a gap in one's knowledge, has been well established as an important motivator behind information-seeking activities Section 1.1. Therefore, search systems that support rapid learning across a number of searchers, and a range of tasks, can be considered as more effective search systems (White, 2016a, p. 310). This dissertation proposal takes a step in this direction. "It opens great expectations for many-sided, great contribution to our knowledge on the relations between search process and learning outcomes" (anonymous reviewer for Bhattacharya, 2021).

1.4 Outline

This dissertation proposal document is structured as follows. First, principles of learning and relevant background from the domain of Educational Sciences are presented in Chapter 2. Next, relevant empirical evidences from the Information Searching Literature are discussed in Chapter 3. Chapter 4 presents the research questions, the overarching hypotheses, and discusses their rationale in the context of the existing research gaps. Chapter 5 describes the research methods, including the longitudinal study design, experimental procedures, data collection and analyses plans, anticipated limitations, and expected schedule to complete the dissertation.

2

Background: Knowledge and Learning

This first chapter on background literature discusses relevant concepts from the disciplines of Education and Learning Sciences. First, we introduce some relevant terminology, and the concepts of deep or meaningful learning. Then we discuss several research backed principles that have been shown to lead to meaningful learning. Next, we discuss how learning, sensemaking, and searching for information are related, and how modern technologies provide affordances for new forms of learning and knowledge work in the 21st century. We also discuss some concepts about individual differences of learners as well as techniques that can promote better learning. In the last section, we state what implications these findings have for shaping the proposed study in this dissertation proposal.

2.1 Terminology

The Webster dictionary[1] defines **knowledge** in two ways. The first definition is "the range of one's information or understanding". Vakkari (2016) says it is "the totality what a person knows, that is, a **personal knowledge** or **belief system**. It may include both justified, true beliefs

[1] https://www.merriam-webster.com/dictionary/knowledge

and less justified, not so true beliefs, which the person more or less thinks hold true." Webster's second definition of knowledge is "the sum of what is known: the body of truth, information, and principles acquired by humankind". We can regard this as **universal knowledge**.

Learning is a *process*, that leads to a *change* in (personal) knowledge, beliefs, behaviours, and attitudes (Ambrose et al., 2010). Thus, learning always aims to increase one's personal knowledge, and can often draw from the body of universal knowledge. In some cases, the change in personal knowledge can also lead to change in universal knowledge, such as when new discoveries are made, or new philosophies are proposed. Human learning is an innate capacity. It is longitudinal and unfolds over time. Learning is lifelong and life-wide, and has a lasting impact on how humans think and act (Ambrose et al., 2010; Kalantzis & Cope, 2012). Learning can be informal or formal. **Informal learning** is the casual learning taking place in everyday life, and is incidental to the everyday life experience. **Formal learning** is the deliberate, conscious, systematic, and explicit acquiring of knowledge (Kalantzis & Cope, 2012).

Education is a form of formal learning. It is the systematic acquiring of knowledge. In today's world, the institutions of education are formally constructed places (classrooms), times (of the day and of life) and social relations (teachers and students); for instance, schools, colleges, and universities. The scientific discipline of Education concerns itself with the systematic investigation of the ways in which humans know and learn. It is the science of "coming to know" (Kalantzis & Cope, 2012).

Pedagogy describes small sequences of learner activities that promote learning in educational settings (Kalantzis & Cope, 2012). Traditional approaches to (classroom) pedagogy, especially the *didactic pedagogy*, primarily involves a teacher telling, and a learner listening. The teacher is in command of the knowledge, and their mission is to transmit this knowledge to the learners, in a one-way flow. It is hoped that the learners will dutifully absorb the knowledge laid before them by the teacher. The balance of agency weighs heavily towards the teacher. "There is a special focus on long-term memory, or retention, measurable by the ritual of closed-book, summative examination" (Cope & Kalantzis, 2017).

Cognitive scientists had discovered that learners retain material better, and are able to generalize and apply it to a broader range of contexts, when they learn **deep knowledge** rather than **surface knowledge**, and when they learn how to use that knowledge in real-world social and practical settings (Sawyer, 2005). Deep learning [2] takes place when "the learner chooses conscientiously to integrate new knowledge to knowledge that the learner already possesses" and involves "substantive, non-arbitrary incorporations of concepts into cognitive structure" (Novak, 2002, p. 549) and may eventually lead to the development of transferable knowledge and skills. A parallel terminology for deep learning (Marton & Säaljö, 1976; Marton & Säljö, 1976) is **meaningful learning** (Ausubel et al., 1968; Novak, 2002), and they are often contrasted with *surface learning* or *rote learning*. Table discusses some more details on deep or meaningful learning, and the limitations of traditional classroom practices to promote deep learning. Figure describes (using a concept map) how meaningful learning can be achieved and sustained, and our annotations highlight how Search-as-learning systems can foster the same.

2.2 Principles of Meaningful Learning

Ambrose et al. (2010) have proposed several principles of (student) learning that lead to creation of deeper knowledge in learners, and help educators understand why certain teaching approaches may help or hinder learning. These principles are based on research and literature from a range of disciplines in psychology, education, and anthropology, and the authors claim they are domain independent, experience independent, and cross-culturally relevant.

1. Students' **prior knowledge** can help or hinder learning.
2. How students **organize knowledge** influences how they learn and apply what they know.
3. Students' **motivation** determines, directs, and sustains what they do to learn.
4. Goal-directed practice coupled with **targeted feedback** enhances the quality of students' learning.

[2] of the human kind

5. Students' current level of development interacts with the social, emotional, and intellectual **context** around the student to impact learning.
6. To become **self-directed** learners, students must learn to **monitor and adjust** their approaches to learning.

In line with the above, the US National Research Council identified several key principles about **experts' knowledge** (National Research Council, 2000), that illustrate the outcome of successful learning:

1. Experts notice features and **meaningful patterns** of information that are not noticed by novices.

2. Experts have acquired a great deal of content knowledge that is **organized** in ways that reflect a deep understanding of their subject matter.

3. Experts' knowledge cannot be reduced to sets of isolated facts or propositions but, instead, reflects contexts of **applicability**: that is, the knowledge is 'conditionalized' on a set of circumstances.

4. Experts are able to **flexibly retrieve** important aspects of their knowledge with little attentional effort.

5. Though experts know their disciplines thoroughly, this does not guarantee that they are able to teach others.

6. Experts have varying levels of flexibility in their approach to new situations.

The principles of learning illustrate that both the *context* of learning, and the *individual differences* of learners moderate the learning process. The findings about expert knowledge suggests that *incorporating new information into existing knowledge structures* in a meaningful manner is a key aspect of learning. We discuss these concepts in more detail in the following sections.

2.3 Meaningful Learning as Sensemaking

In this section, we discuss how meaningful learning can be further qualified using the concepts of sensemaking. **Sensemaking**[3] is a process that occurs when learners *connect* their *previously developed* knowledge, ideas, abilities, and experiences together to address the uncertainty presented by a newly introduced phenomenon, problem, or piece of information (Next Generation Science Standards, 2021). A significant portion of learning is sensemaking, especially those which use recorded information or systematic discovery to learn concepts, ideas, theories, and facts in a domain (such as science or history) (Zhang & Soergel, 2014). The phrase "figure something out" is often synonymous with sensemaking. Sensemaking is generally about actively trying to figure out the way the world works, and/or exploring how to create or alter things to achieve desired goals (Next Generation Science Standards, 2021). (Dervin & Naumer, 2010) distinguish work on sensemaking in four fields: "Human Computer Interaction (HCI) (Russell's sensemaking); Cognitive Systems Engineering (Klein's sensemaking); Organizational Communication (Weick's sensemaking; Kurtz and Snowden's sense-making); and Library and Information Science (Dervin's sense-making)".

Many theories of learning and sensemaking revolve around the concept of fitting new information into an existing or adapted knowledge structure (Zhang & Soergel, 2014). The central idea is that knowledge is stored in human memory as *structures* or *schemas*, which comprise interconnected concepts and relationships. When new information is encountered or acquired, the learner or sensemaker needs to actively construct a revised or entirely new knowledge structure. Examples of some such theories include: the *assimilation theory (theory of meaningful learning)* (Ausubel et al., 1968; Ausubel, 2012; Novak, 2002; Novak, 2010); the *schema theory* (Rumelhart & Norman, 1981; Rumelhart & Ortony, 1977); and the *generative learning theory* (Grabowski, 1996; Wittrock, 1989); all of which have their foundations in the Piagetian concepts of *assimilation* and *accommodation* (Piaget, 1936).

[3] "Brenda Dervin, one of the originators of the sense-making methodology, prefers the spelling with a hyphen, while the community in computer science and more technical people in information science (e.g., SIGCHI) use sensemaking without a hyphen" (Zhang & Soergel, 2014).

Assimilation means addition of new information into an existing knowledge structure. A "synonym" (Vakkari, 2016) for assimilation is **accretion**, which is the gradual addition of factual information to an existing knowledge structure, without structural changes. Accretion does not change concepts and their relations in the structure, but may populate a concept with new instances or facts. **Accommodation** means modifying or changing existing knowledge structures, by adding or removing concepts and their connections in the knowledge structure. Accommodation is subdivided into *tuning* / *weak-revision*, and *restructuring*, based on the degree of structural changes (Zhang & Soergel, 2014). **Tuning** or **weak revision** does not include replacing concepts or connections between concepts in the structure, but tuning of the scope and meaning of concepts and their connections. This may include, for example, generalizing or specifying a concept. **Restructuring** means radically changing and replacing concepts and their connections in the existing knowledge structure, or creating of new structures. Such radical changes often take place when prior knowledge conflicts with new information. New structures are constructed either to reinterpret old information or to account for new information (Vakkari, 2016; Zhang & Soergel, 2014). A comparison of these types of conceptual changes can be found in (Zhang & Soergel, 2014 Table 3).

2.3.1 Concept Maps to enhance Sensemaking

As we saw in the previous section, deep learning / meaningful learning / sensemaking is a process in which new information is connected to a relevant area of a learner's existing knowledge structure. However, the *learner must choose* to do this, and must actively seek a way to integrate the new information with existing relevant information in their cognitive structure (Ausubel et al., 1968; Novak, 2010). Learning facilitators (e.g., teachers) can encourage this choice by using the concept mapping technique.

A **concept-map** is a two-dimensional, hierarchical node-link diagram (a *graph* in Computer Science parlance) that depicts the structure of knowledge within a discipline, as viewed by a student, an instructor, or an expert in a field or sub-field. The map is composed of concept labels, each enclosed in a box (graph *nodes*); a series of labelled linking lines (*labelled edges*); and an inclusive, general-to-specific organization (Halttunen & Jarvelin, 2005). Concept-maps assess how well students see the ''big picture", and where there are knowledge-gaps and misconceptions. A *mind map* is a diagram similar to a concept map, comprising nodes and links between nodes. However, mind maps emerge from a single centre, and have a more hierarchical, tree like structure. Concept maps are more free-form, allowing multiple hubs and clusters. Also, mind-maps have unlabelled links, and are subjective to the creator. There are no "correct" relationships between nodes in a mind map. Figure shows the key features of a concept map, with the help of a concept map.

Concept maps are therefore, arguably the most suited mechanism to represent the cognitive knowledge structures, connections, and patterns in a learner's mind. Conventional tests, such as multiple choice questions, are best at assessing students' recall of facts and guessing skills. Their format treats information as distinct and separate items, rather than interconnected pieces of a bigger picture. Concept maps on the other hand, encourage learners to identify and make connections between concepts that they know, and concepts that are new to them. Concept maps have been used for over 50 years to provide a useful and visually appealing way of illustrating and assessing learners' conceptual knowledge (Egusa et al., 2010, 2014a, 2014b, 2017; Halttunen & Jarvelin, 2005; Novak, 2010; Novak & Gowin, 1984).

Analysis of concept maps can reveal interesting patterns of learning and thinking. Some of these measures that have been used by (Halttunen & Jarvelin, 2005) are: addition, deletion, and differences in top-level concept-nodes; depths of hierarchy; and number of concepts that were ignored or changed fundamentally. In this regard, (Novak & Gowin, 1984) have presented well-established scoring schemes to evaluate concept-maps: 1 point is awarded for each correct relationship (i.e. concept–concept linkage); 5 points for each valid level of hierarchy; 10 points for each valid and significant cross-link; and 1 point for each example.

Having discussed how deep learning / meaningful learning / sensemaking involves creation of knowledge structures in the learner's mind, and suitably adding new pieces of information in the knowledge structure, we now discuss how these processes are influenced in the 21st century with the presence of new media, digital technologies, and information retrieval systems.

2.4 'New' Learning as Online Information Searching

Digital media technologies and e-learning 'ecologies' can enable new forms and models of learning, that are fundamentally different from the traditional classroom practices of didactic pedagogy (Cope & Kalantzis, 2017). Some key concepts associated with these forms of 'new learning' are described below. These concepts from the Educational Sciences domain tie back strongly to the issues, challenges, and research agenda being investigated by researchers in the Search as Learning and Information Retrieval domain (Section 1.1.

2.4.1 Active Knowledge Making

The Internet and new forms of media provide us the opportunity to create learning environments where learners are no longer mainly *consumers* of knowledge, but also *modifiers*, *producers*, and *exchangers* of knowledge. In **active knowledge making**, learners can, and often need to, find information on their own using online resources. They are not restricted to the textbook alone. The Internet is often a definitive resource for information on any given topic. A learner can search the web (to learn) at any time, from anywhere, on any web-enabled device.

As knowledge producers, learners search and analyze multiple sources with differing and contradictory perspectives, and develop their own observations and conclusions. In this process, they become researchers themselves and learn to collaborate with peers in knowledge production. Collaboration gives learners the opportunity to work with others as coauthors of knowledge, peer reviewers, and discussants to completed works. Because learners bring their own views, outlooks, and experiences, the knowledge artefact they create is often uniquely voiced instead of a templated "correct" response (Amina, 2017).

> *Learners become **active knowledge producers** (for instance, project-based learning, using multiple knowledge sources, and research based knowledge making), and*

> *not merely knowledge consumers (as exemplified in the 'transmission' pedagogies of traditional textbook learning or e-learning focused on video or e-textbook delivery). Active knowledge making practices underpin contemporary emphases on innovation, creativity and problem solving, which are quintessential 'knowledge economy' and 'knowledge society' attributes.* — Cope & Kalantzis (2017)

2.4.2 Artefacts for Learning Assessment

Traditionally, the focus of learning outcomes has been long term memory. Students and learners were expected to remember a collection of facts, definitions, proofs, equations, and other associated details. For a significant amount of modern knowledge-work today, **memory is actually less important**. Information is so readily accessible now that it is no longer necessary to remember the information. Because of the technological phenomenon, the mass of information is available ubiquitously [4] to a learner (or a knowledge worker), in every moment of learning. Empirical details such as facts, definitions, proofs, or equations do not need to be remembered today, because they can always be looked up again (Amina, 2017; Cope & Kalantzis, 2017).

This creates an interesting shift in the focus of learning and knowledge work today: *"if we are not going to measure and value long-term memory in education, what are we going to assess?"* Cope & Kalantzis (2017) suggest that **we assess the knowledge artefacts** that learners produce. In active knowledge making, the final work [5] can be proof of the learning outcome and represent a learner's ability to use the resources that are available (Amina, 2017). **Measure of learning can be measure of information quality and information use in artefacts.** This shows a shift in pedagogy and assessment and an increase in personalization and individualization of learning (Pea & Jacks, 2014). Memorizing the information on a topic is less important, compared to the writing, synthesizing, analyzing, and **sensemaking** of the available information that has been referenced in the work. This shifts the focus of assessment to the quality of the artefacts and the processes of their construction. Moreover, as technology increases the ability to capture detailed data from formal and informal learning activities, it

[4] as long as there is internet connection

[5] be it a project report, poster, presentation, video, software,research paper, website, etc.

can give us a new view of how learners progress in acquiring knowledge, skills, and attributes (DiCerbo & Behrens, 2014). Because learning is a continuous, longitudinal process, these advanced, technologically enhanced assessments are more useful in understanding the learning process and knowledge development (Amina, 2017).

Assessing open-ended artefacts does come with its challenges and limitations. First, assessing and grading artefacts requires the development of detailed qualitative coding guides (Wilson & Wilson, 2013). This process involves defining grading criteria and measuring inter-coder agreement to ensure that the coding guide is reliable. Prior studies have scored summaries along dimensions such as the inclusion of facts, relationships between facts, and evaluative statements (Lei et al., 2015; Roy et al., 2021; Wilson & Wilson, 2013). Second, the quality of responses may be difficult to compare across learners. Since this type of assessment imposes very few constraints on the learners' responses, it may cause some learners to *satisfice*, and not convey everything that was learned. Additionally, writing skills are likely to vary across learners, and some may not be able to effectively articulate everything that was learnt.

2.4.3 'Information Search and Evaluation' as and for Learning

Learning today is more about **navigation, discernment, induction, and synthesis**, and less about memory and deduction (Cope & Kalantzis, 2013). However, knowing the source, finding the source, and using the information critically is important to learn and know now more than ever before (Amina, 2017). Learners must know the social sources of knowledge and understand and correctly use quotations, paraphrases, remixes, links, citations, and the like in the works that they develop. Searching and sourcing from the web entails a process of developing and completing a work that inevitably makes learners **knowledge producers**, as long as they can navigate and critically discern the value of multiple sources. This is a skill that must be learned, as many sources of information are not valid, reliable, or authentic (McGrew et al., 2018; Wineburg & McGrew, 2016). Understanding the different sources and identifying the more reliable ones are essential for effective teaching and learning (McGrew et al., 2017; McGrew, 2021). This is a critical aspect because the inability to cite properly or to use reliable resources provides learners with misconstrued information and ideas (Amina, 2017; Breakstone et al., 2021; McGrew et al., 2017).

The Stanford History Education Group (SHEG) conceptualised the **Civic Online Reasoning** (COR) curriculum [6] to enable students to effectively search for and evaluate online information (Breakstone et al., 2018; Breakstone et al., 2021; McGrew, 2020). The curriculum centres on asking three questions of any digital content: *(i)* who is behind a piece of information? *(ii)* what is the evidence for a claim? *(iii)* what do other sources say? The curriculum has lessons and assessments for information evaluation skills such as lateral reading (Wineburg & McGrew, 2017), identifying news versus opinions, checking domain names, identifying sponsored content, evaluating evidence, and practising click restraint (McGrew & Glass, 2021). The lessons were developed and piloted by the Stanford History Education Group (McGrew et al., 2018; McGrew, 2020; McGrew & Glass, 2021). Taken together, these strategies will allow academics and students to better evaluate digital content, from the perspectives of professional fact checkers.

The purview of the *Civic Online Reasoning* curriculum is more targeted than the expansive fields of media and digital literacy [7], (which can embrace topics ranging from cyberbullying to identity theft). Civic Online Reasoning focuses squarely on how to sort fact from fiction online, a prerequisite for responsible civic engagement in the twenty-first century (Breakstone et al., 2021; Kahne et al., 2012; Mihailidis & Thevenin, 2013).

2.5 Promoting Better Learning

> *It is not the technology that makes a difference; it is the pedagogy.*
>
> — Cope & Kalantzis (2017)

[6] `https://cor.stanford.edu`

[7] *"Digital literacy describes a holistic approach to cultivating skills that allow people to participate meaningfully in online communities, interpret the changing digital landscape, understand the relationships between systemic -isms and information, and unlock the power of digital tools for good. This includes media literacy. Terms like critical media literacy, media literacy, news literacy, and more are not necessarily interchangeable."* – Collins (2021)

Having discussed how meaningful learning takes place, and how it is influenced by the presence of digital media and the mass of information on the Internet, let us now look deeper into the learners as persons themselves. In this section, we discuss how different cognitive and metacognitive practices and aspects of learners can promote better learning. These phenomena have important implications for any digital systems that aim to foster learning.

2.5.1 Externalization and Articulation

The learning sciences have discovered that when learners externalize and articulate their developing knowledge, they learn more effectively (National Research Council, 2000). Best learning takes place when learners articulate their unformed and still developing understanding, and continue to articulate it throughout the process of learning. This phenomenon was first studied in the 1920s by Russian psychologist Lev Vygotsky. Articulating and learning go hand in hand, in a mutually reinforcing feedback loop. Often learners do not actually learn something until they start to articulate it. While thinking out loud, they learn more rapidly and deeply than while studying quietly (Sawyer, 2005). The learning sciences community is actively researching how to support students in their ongoing process of articulation, and which forms of articulation are the most beneficial to learning. Articulation is more effective if it is scaffolded – channelled so that certain kinds of knowledge are articulated, and in a certain form that is most likely to result in useful reflection (Sawyer, 2005). Students need help in articulating their developing understandings, as they do not yet know how to think about thinking, or talk about thinking; their knowledge state is *anomalous* (Belkin et al., 1982).

2.5.2 Metacognition and Reflection

One of the reasons that articulation is so helpful to learning is that it promotes *reflection* or *metacognition*. **Metacognition**, commonly referred to as thinking about thinking, involves thinking at a higher level of abstraction, which in turn improves thinking and learning (Blanken-Webb, 2017). It is "the process of reflecting on and directing one's own thinking" (National

Research Council, 2000, p. 78), and involves thinking about the process of learning, and thinking about knowledge. This ties forward to the self-regulation that effective learners exhibit (Section 2.5.4). Effective learners are aware of their learning process, and can measure how efficiently they are learning as they study.

The literature on metacognition broadly identifies two fundamental components of metacognition: knowledge about cognition, and regulation of cognition. **Knowledge about cognition** includes three subprocesses that facilitate the *reflective* aspect of metacognition: declarative knowledge (knowledge about self and about strategies), procedural knowledge (knowledge about how to use strategies), and conditional knowledge (knowledge about when and why to use strategies). **Regulation of cognition** include a number of subprocesses that facilitate the *control* aspect of learning. Five component skills of regulation have been discussed extensively in the literature, including planning, information management strategies, comprehension monitoring, debugging strategies, and evaluation. The operational definitions of these components are described in Table . Schraw & Dennison (1994) developed the **Metacognitive Awareness Inventory** (MAI) survey and a scoring guide to measure these self-reported components and subprocesses of metacognition. The original survey consists of 52 true/false questions (Appendix B.7), such as "*I consider several alternatives to a problem before I answer*", "*I understand my intellectual strengths and weaknesses*", "*I have control over how well I learn", and "I change strategies when I fail to understand*". The instrument has been widely used in research, and has its reliability and validity measures available. Later, Terlecki & McMahon (2018) proposed a revised version of the MAI, using five-point Likert-scales, ranging from "*I never do this*" to "*I do this always*". They argue that when measuring change in metacognition over time, the Likert-scale based 'how often' questions are more effective than dichotomous 'Yes/No' questions (Terlecki, 2020; Terlecki & McMahon, 2018).

2.5.3 Motivation

Motivation is the process that initiates, guides, and maintains goal-oriented behaviours (Cherry, 2020). The **Self-Determination Theory** (SDT) represents a broad framework for the study of human motivation and personality (Ryan & Deci, 2017). SDT differentiates the types of motivation based on the reasons that give rise to behaviour: intrinsic motivation and extrinsic motivation. **Intrinsic motivation** is engaging in a task or behaviour for the rewards *inside* the task or behaviour, such the pleasure, enjoyment and satisfaction that the behaviour provides. It is a stable form of motivation. **Extrinsic motivation** is engaging in a task or behaviour for the rewards *outside* the task or behaviour, such as receiving rewards, avoidance of punishment, gaining social approval, or achievement of a valued result. Extrinsic motivation is on a continuum from less stable to more stable, as illustrated in Figure **??**. Extrinsic motivation does not last unless the rewards and punishments are explicitly visible (Deci & Ryan, 2013; Ryan & Deci, 2000; Tahamtan, 2019).

(Ryan, 1982) proposed the **Intrinsic Motivation Inventory** (IMI) (Appendix B.5, a multidimensional questionnaire intended to assess participants' subjective experience related to a target activity in laboratory experiments. The instrument assesses participants' interest/enjoyment, perceived competence, effort, value/usefulness, felt pressure and tension, and perceived choice while performing a given activity, yielding six subscale scores. The *interest/enjoyment* subscale is considered the most indicative self-report measure of intrinsic motivation. The *perceived choice* and *perceived competence* concepts are theorized to be positive predictors of both self-report and behavioral measures of intrinsic motivation. The *pressure/tension* is theorized to be a negative predictor of intrinsic motivation. *Effort* is a separate variable that is relevant to some motivation questions, so it is used if its relevant. The *value/usefulness* subscale is used to measure internalization, with the idea being that people internalize and become self-regulating with respect to activities that they experience as useful or valuable for themselves.

2.5.4 Self-regulation

Self-regulation is the ability to develop, implement, and flexibly maintain planned behaviour in order to achieve one's goals. Self-regulation, and more broadly, self-direction, are critical to being an effective "lifelong" learner. Self-regulation becomes increasingly important at higher levels of education and in professional life, as people take on more complex tasks and greater responsibilities for their own learning. However, these metacognitive skills tend to fall outside the content area of most courses, and therefore, often neglected in instruction (Ambrose et al., 2010, p. 191). Building on the foundational work of (Kanfer, 1970b, 1970a), Miller and Brown formulated a seven-step model of self-regulation (J. Brown, 1998; Miller & Brown, 1991). In this model, behavioural self-regulation may falter because of failure or deficits at any of these seven steps: *(i)* receiving relevant information, *(ii)* evaluating the information and comparing it to norms, *(iiii)* triggering change, *(iv)* searching for options, *(v)* formulating a plan, *(vi)* implementing the plan, and *(vii)* assessing the plan's effectiveness (which recycles to steps *(i)* and *(ii)*). Although this model was developed specifically to study addictive behaviours, the self-regulatory processes it describes are meant to be general principles of behavioural self-control. (J. M. Brown et al., 1999) developed the **Self-Regulation Questionnaire** (SRQ) (Appendix B.6) to assess these self-regulatory processes through self-report. The items were developed to mark each of the seven sub-processes of the (Miller & Brown, 1991) model, forming seven subscales of the SRQ. The 63-item scale elicits responses in the form of 5-point Likert scale, ranging from strongly disagree to strongly agree. Based on clinical and college samples, the authors tentatively recommend a score of 239 and above as high (intact) self-regulation capacity (top quartile), 214-238 as intermediate (moderate) self-regulation capacity (middle quartiles), and 213 and below as low (impaired) self-regulation capacity (bottom quartile).

2.5.4.1 Self-directed and Self-regulated Learning

As we saw in the previous sections, self-regulation, motivation, and metacognition are key concepts that moderate the learning process. These terms are couched in the concepts of self-regulated learning and self-directed learning.

Self-directed learning (SDL) is a "process in which individuals take the initiative, with or without the help from others, in diagnosing their learning needs, formulating goals, identifying human and material resources, choosing and implementing appropriate learning strategies, and evaluating learning outcomes"(Knowles, 1975, p. 18). **Self-regulated learning** (SRL) can be described as the degree to which students are "metacognitively, motivationally, and behaviourally active participants in their own learning process" (Zimmerman, 1989, p. 329).

Often used interchangeably, self-directed learning (SDL) and self-regulated learning (SRL) have some important similarities and differences (Figure **??**) (Saks & Leijen, 2014). SDL, originating from adult education, is a broader, macro-level construct, and is usually practised outside the traditional school environment. The self-directed learner is free to design their own learning environment, and free to plan and set their own learning goals. SRL, on the other hand, is a narrower, micro-level construct, originating from educational and cognitive psychology, and is mostly utilized in the school environment. Learners do not have as much freedom as in SDL. The instructor or facilitator often defines the learning task and the learning goals. Self-directed learning may include self-regulated learning, but the converse is not true (Jossberger et al., 2010; Loyens et al., 2008). In other words, *"a self-directed learner is supposed to self-regulate, but a self-regulated learner may not self-direct"* (Saks & Leijen, 2014). Despite their differences, SDL and SRL share key similarities (Saks & Leijen, 2014). First, both can be seen in two dimensions: *(i) external* to the learner, as a process or series of events, and *(ii) internal* to the learner, arising from the learner's personality, aptitude, and individual differences. Second, both the learning processes have four key phases: *(i)* defining tasks, *(ii)* setting goals and planning, *(iii)* enacting strategies, and *(iv)* monitoring and reflecting. Third, both SDL and SRL require active participation, goal-directed behaviour, metacognition, and intrinsic motivation.

In summary, metacognition is monitoring and controlling what is in the learner's head; self-regulation is monitoring and controlling how the learner interacts with their environment; self-regulated learning is the application of metacognition and self-regulation to learning (Mannion, 2020); and the whole learning process is sustained by motivation, which is desirable to be intrinsic.

2.6 Summary and Implications for this Proposal

In this first chapter of the background literature review, we discussed *(i)* what is meaningful learning, a.k.a. deep learning, or sensemaking; *(ii)* how meaningful learning updates the learner's cognitive knowledge structure; *(iii)* how the learning process is influenced by digital technologies, mass of information on the Internet, and IR systems; and *(iv)* what principles and practices learners and educators must realize and follow to promote meaningful learning. These findings are from the domains of Educational Sciences, Learning Sciences and Cognitive Sciences. We argue that these are important aspects to be considered when designing future IR or educational information systems that aim to combine and improve the searching and learning experience.

Guided by these findings, we make some important decision choices for the proposed longitudinal study in this dissertation proposal. We aim to situate learners in their context, and incorporate their individual differences using metacognition, motivation, and self-regulation characteristics. Additionally, we aim to assess learning using artefacts and concept maps. We choose not use traditional tests like question-answers, and multiple choice assignments, since they are often not the preferred choice of knowledge-work output in real world scenarios. Concept maps are better suited to represent the learning and sensemaking process, and artefacts are better able to demonstrate a learner's knowledge work.

In the next chapter, we look at relevant literature from the Information Sciences and Interactive Information Retrieval disciplines.

3
Background: Information Searching

4
Research Questions and Hypotheses

5

Methods: Longitudinal Study

5.1 Study Design

5.2 Apparatus

5.2.1 YASBIL Browsing Logger

5.2.2 Qualtrics Survey Software

5.2.3 Zoom Video-conferencing Software

5.3 Search Task Template

5.4 Procedure

Insert diagram and check how it looks

Reference it

	ENTRY SURVEY [SUR1]	INITIAL SESSION [SES1]	LONGITUDINAL TRACKING [SES2a, SES2b, SES2c SES2d]	MID-TERM SURVEY [SUR2]	FINAL SESSION [SES3]	EXIT SURVEY [SUR3]
Why	Record individual-differences	Establish baseline search behaviour and initial knowledge	Understand change in search behaviour and knowledge acquisition over time	Track changes in individual differences	Record "evolved" search behaviour, and "final" knowledge	Final state of individual differences
When	Week 1-2 of semester	Weeks 1-2 of semester; after SUR1	Four different points over the semester	Semester mid-point	After last day of classes	Anytime after SES3
Where	Asynchronous	**Synchronous**: Remote	Async	Async	**Sync:** Remote	Async
What	Only in SUR1: −Consent Form −Search Exp. & IT proficiency Repeated in SUR2 and SUR3: −Course Load −Note-taking strategies −Motivation −Self-regulation −Metacognition	**Two search tasks:** for each task, participants searched to find at least three unique, good quality online resources relevant to a given topic. • Pre-search self reporting: existing knowledge, interest, perceived difficulty • Post-search self reporting: perceived learning, perceived search success, interest and motivation, decision making **One website reliability assessment** from Stanford History Education Group (SHEG)	Participants recorded browsing activity when they worked on **final project assignment –** writing a research paper – at four different points in the semester. − SESa: Proposal − SES2b: Paper Outline − SES2c: Rough Draft − SES2d: Final Paper Participants also shared (anonymized) assignment submission	Similar to SUR1, with repeated components	**Two search tasks:** one task-topic repeated from SES1, one new; same format as SES1 **One website reliability assessment** from SHEG (topic different from SES1) **Semi-structured interview:** reflection on searching and learning experience.	Similar to SUR2 Participants self-reported scores and grades they received for different parts of the final project
Approx. Time Reqd.	10 - 15 mins	60 - 90 mins	No time limit for working on assignments. Sharing data with researchers took 1-5 minutes.	10 - 15 mins	60 - 90 mins	10 - 15 mins
Comp: (USD) $150	$5	$25	$5, $5, $10, $15 (total $35)	$10	$30	$15
	Bonus $30 paid in the end, if participant completed all parts of the study.					

Figure 5.1: Very very very very very very very very long caption.

5.4.1 SUR1: Entry Survey

5.4.2 SES1: Initial Session

5.4.3 SES2a - SES2d: Longitudinal Tracking Sessions

5.4.4 SUR2: Mid-Term Survey

5.4.5 SES3: Final Session

5.4.6 SUR3: Exit Survey

6
Data Analysis

Note about pronouns: all participants are referred to using gender-neutral they/them pronouns.

Final feedback: P022Pisa said > *It is great to be able to participate in the research this semester. Using the extension somehow brings me postive feedback and that helps me in study I303. So I wanna say thank you* > - P022Pisa

6.1 Data Cleaning and Processing

see crescenzi thesis

6.2 URL Categorization

- peer-reviewed publications are `PUB`s
- others are `ARTICLE`s (e.g. Wikipedia)
- if no other info, then `WEB`
- fuzzy between `WEB` and `ARTICLE` (when classified manually)
- `ARTICLE` if there is a clear author

  - except `WIKIPEDIA`, due to common parlance
  - encyclopedias

- journal homepages are `WEB`
- list of chapters in a book are `L.PUB`.
  - e.g. in detail view of
- book chapter is `PUB`

6.3 User characteristics: Latent Profiles

- feature sets for profiling (toggle on and off)
  - `IMI`
  - `MAI`
  - `SRQ`
  - `WMC` / memory span:
    - scaling by dividing by 10 (?) (that's the max Coglab would show)

Memory span values normalized by 10, because "*The maximum memory span measurable with this experiment is ten*" as per CogLab output

- [st]Use LIME / SHAP and counterfactual explanations to understand which components contribute to change in Profile Membership
- no no; a simple examination of what feature values changed between timepoints will be enough
- use 2 groups! 2 groups is always better. easier to explain; easier to write.

6.4 Search Behaviour Data Analysis Approach

From White (2016a), Table 2.1 (adapted from Bates, 1989):

- **Level 1: Move**
  - Atomic search event – for example, a query or click (*An identifiable thought or action that is part of information searching.*)
- **Level 2: Tactic**
  - Goal or task, including query or click chain (*One or several moves made to further a search*)
- **Level 3: Statagem**
  - Mission or session (*A larger, more complex set of thoughts and/or actions than the tactic; a stratagem consists of multiple tactics and/or moves, all of which are designed to exploit a particular search domain that is thought to contain the desired information*)
- **Level 4: Strategy**
  - Session or cross-session search task (*A plan, which may contain moves, tactics, and/or stratagems, for an entire information search.*)

6.5 Level 1: Moves - Query Reformulation

- Yung Sheng's Dissertation
- (Hassan et al., 2014) Table 1

Measures:

- Number of terms per Query

- Query length (characters?)
- Number of (unique) queries per search
- Number of reformulated query types
- Abandoned Queries (Percentage of queries with no clicks)
- query similarity (Hassan et al., 2014)
  - average similarity between all queries to the first query in every session
  - exact match, approx match, lemma match, semantic match

6.6 Level 1: Moves - Dwell Time (DT)

Dwell Time categories:

- `short`
  - 1 <= DT <= 5s
  - "*A time span of less than 5 seconds is a too short period for being able to read a summary and extract information*" (He et al., 2016).
- `med`
  - 5 < DT <= 30s
- `long`
  - DT > 30s
  - from Handehawa's thesis, and related Shah references

Other Ideas

- do analysis of `LIB` and `LIBGUIDE` type URLs - library websites
- Dwell Time:
  - overall

  - per-task
  - per timepoint?
- sig diff in DT between
  - `SES1` and `SES3`
  - `SES2a` and `SES2d`?
- checkout: `sns.pairplot()` – pairwise relationships in a dataset
  - https://seaborn.pydata.org/generated/seaborn.pairplot.html
- checkout seaborn's plotting capabilites!

6.7 Level 1: Moves - Other Behaviour

- `TAB`: Parallel Browsing Events
  - `open`
  - `switch`
  - `close`
- `SESSION`: from YASBIL events and `task_id`
  - `start`
  - `end`
- `IDLE`: user stays idle for 1 minute (Taramigkou et al., 2018)

6.8 Level 2: Implicit Features for Exploratory Search Process

From Hendahewa (2016) and related papers.

- **Creativity** –> Information Novelty

- **Unique Coverage:** Unique web pages visited
- **Likelihood of Discovery:** Measurement of difficulty to find certain information

- **Exploration**
  - **Total Coverage:** Total number of content pages visited
  - **Distinct Queries:** Total number of different queries issued
  - **Query diversity:** Measurement of similarity between queries issued

- **Knowledge Discovery** –> Finding useful and relevant information
  - **Useful Coverage:** Number of pages where users spend a considerable amount of time
  - **Relevant Coverage:** Number of pages that users denote as relevant to the task

https://rucore.libraries.rutgers.edu/rutgers-lib/49207/

6.9 Level 2+: Search Tactics and Strategies

Pernilla Q et al's paper: Jiyin He, Pernilla Qvarfort, Martin Halvey, Gene Golovchinsky. Beyond actions: Exploring the discovery of tactics from user logs. In Information Processing & Management, vol. 52, issue 6, Nov. 2016, pp. 1200–1226.

- http://dx.doi.org/10.1016/j.ipm.2016.05.007
- https://www.pernillaq.com/exploratory-search
- checkout the forward citations of this paper on automated log analyses
- like process mining!
- "*Since modern search systems may allow user interactions beyond the tactics defined in the literature the tactics may need to be extended*"

Behaviours from *Search Patterns* book

- quit
- narrow
- expand
- pearl growing / citation mining / snowballing
- pogo sticking
- thrashing

6.9.1 Strategies from Dwell Time (DT)

Tactics

- Q.{types of reformulations}
- L.{DT categories}
- L.click (only hyperlink clicks)
- I.{DT categories}
- I.click
- OTHER.{DT categories}
- TAB.{tab events}
- IDLE
- SESSION.{session events}

6.9.2 Strategies from webpage L2 categories

Tactics

- Q.{types of reformulations}
- L.{`PUB` / `WEB` / `X`}
- L.click (only hyperlink clicks)
- I.{`PUB` / `WEB` / `ARTICLE` / X}
- I.click

- OTHER.{`X`}
- TAB.{tab events}
- IDLE
- SESSION.{session events}

6.9.3 Strategies from Lam et al. (2007)

- As in (Lam et al., 2007) Sec 6 (`S` to denote a Search event and `X` to denote a non-search engine event):
  - Short Navigation: S(Start) –> X (End), with the S event limits to the first session events and the X event to the last events.
  - Topic Exploration: S –> X –> X –> X –> X –> ...
  - Methodical Results Exploration: S –> X –> S –> X –> S ...
  - Query Refinement: S –> S –> S –> S ...
- Using `WebNavigation` events and tab switches
- can do sequential pattern mining as in (Ibáñez & Simperl, 2022)
  - maximal sequential pattern
  - etc.
- Other search patters:
  - `SS`: Search-engine Searches
  - `TS`: Third-party Searches using third-party online sites as search engines
  - `TE`: True Explorations of search results

6.9.4 Struggling vs. Exploring

Indicators predictive of struggling (Hassan et al., 2014):

- low amount of similarity between consecutive queries

- more clicks per query
- differences in the nature of the reformulation patterns: less query term substitution and more addition/removal with exploring

6.9.5 Navigators vs. Explorers

From IWSS book (later, low priority)

6.9.6 Transition analysis of Search Tactics / Strategies

Transition analysis can be applied to:

- search tactics
- tabs: parallel browsing behaviour (think hard... do we need a constant number of tabs for this to work?)
- combined (opening tab and closing tabs are tactics / events in Markov process)

Help with analyses:

- Chen and Cooper (2002) used a Chi-square test to compare the distribution of transitions in search tactic transition matrices.
- (He et al., 2016, p. 1220 sec 6.1) for calculation formulas for entropy of transitions
- (Krejtz et al., 2014) sec 4 for calculation formulas
- (He et al., 2016, p. 1220 sec 6.2) for hypotheses

6.10 Correlation analysis

Correlation between user profiles and search tactics (Table 9 Taramigkou et al., 2018)

7

Results and Discussion

What about learning?? What are the measures of learning?

- Also see Yung Sheng's Dissertation
- think hard about which data component has not been touched / analysed

Hypotheses from He et al. (2016):

The second set (H2) compares two different user groups, experts and novices, using one of the search systems in two different conditions. The H2 hypotheses illustrate how a focus on search tactics provides a different lens to view search logs.

- H2.1: Search experts are likely to be more predictable in their choice of search tactics compared to novices
- H2.2: Search experts have developed a set of search tactics they prefer over others, while novices use search tactics more uniformly.
- H2.3: While working with a search system novices will find a preferred method of transitioning from one search tactic to another. In other words, their search tactics transitions will become more predictable over time.

- H2.4: While working with a search systems novices will find preferred search tactics to use. In other words, their distribution of search tactics will become less uniform over time.

7.1 Descriptive statistics

7.1.1 profile transitions

- how the following changed over time
  - motivation, metacognition, self regulation
  - perceived learning, perceived search outcome

7.2 Q - query (re)formulation

7.3 L - source selection / Item Selection

- dwell times
- "Item" selection as in IWSS

7.4 I - interacting with sources

- dwell times

> *If the dwell time is long, i.e. 5 seconds, it is more likely that a user is reading the search results summary (ER) rather than only skimming it (EI). The 5 second threshold was determined based on reading research using eye tracking (Rayner, 1998) and the size of the summaries in Querium. A time span of less than 5 seconds is a too short period for being able to read a summary and extract information.*
>
> — He et al. (2016)

7.5 Overall search behaviour

7.5.1 search tactics

7.6 SHEG tasks - information evaluation capabilities

> *We've confused young people's ability to operate digital devices with the sophistication they need to discern whether the information those devices yield is something that can be relied upon*
>
> https://twitter.com/suzettelohmeyer/status/1617909351766757376 https://www.grid.news/story/misinformation/2023/01/23/will-information-literacy-in-schools-fix-our-misinformation-problem/

7.7 Qualitative / Free Text Results

Note-taking strategies

- how do you organize your notes
- how long do you store your notes
- how do you search for a bit of info in the notes

Other surveys

7.8 Discussion - Research Questions

7.8.1 RQ1: - search behaviours?

7.8.2 RQ2: mention here

7.8.3 RQ3: mention here

7.8.4 RQ4: mention here

8 Conclusions, Contributions, and Future Work

see Jacek's thesis

8.1 Research Summary

8.2 Summary of Results

8.3 Methodology

8.4 Contributions

From ASIST award session

FOLLOW UP WITH ...

- Change of the self, self-reflection
- Look at anthropology perspective

ROB:

- Look at qualitative data. More interesting

HEATHER:

- what can we share back to the teachers of the course, librarians and others

8.5 Limitations

- No PDF
- N=16 to N=10
- Also check anticipated limitations section from proposal

8.6 Future Work

Appendices

A
Prior Work: Pilot Study

A.1 SES1: Initial Session

B
SUR1: Entry Survey

B.1 Demographics

1. Please select the degree level/name of the program you are in.
2. Please state which year of the program you are in.
3. Please state your major(s)
4. Do you have native-level familiarity with English language? Yes / No / Other:
5. Please state your age (in years)
6. Please state your gender
7. With which ethnicities do you identify? Please check all that apply:
    - African
    - African American / Black
    - Asian - East
    - Asian - South East
    - Asian - South
    - Asian - Middle East
    - Caucasian / White

- Hispanic / Latinx
- Native American
- Pacific Islander
- Mixed
- Other: ______

8. Are you an international student? Yes / No; If Yes, where are you originally from?
9. Please enter an email address that you check regularly. We will send communications and compensation information to this email address.
10. Your name as you would like us to address you.

B.2 Search and IT Proficiency

1. Which device(s) and browser(s) do you normally use to surf the internet?

Choice	Chrome (1)	Safari (2)	Firefox (3)	Edge (4)	Opera (5)	Other (6)	None (7)
Desktop							
Laptop							
Tablet							
Smartphone							

2. How comfortable are you with using Mozilla Firefox to search information on the internet?

   1. I do not know how to use Mozilla Firefox.
   2. I have never used Mozilla Firefox.
   3. I feel very uncomfortable to use Mozilla Firefox.
   4. I feel uncomfortable to use Mozilla Firefox.
   5. I feel neither comfortable nor uncomfortable to use Mozilla Firefox.
   6. I feel comfortable to use Mozilla Firefox.

7. I feel very comfortable to use Mozilla Firefox.
8. Other: ______

3. Which search engines do you normally use?

1. Google
2. Bing
3. Baidu
4. Yahoo!
5. Yandex
6. DuckDuckGo
7. Other:

The following items are adapted from the **Digital Health Literacy Instrument (DHLI)** by Van Der Vaart & Drossaert (2017).

On a scale of 1 to 5 ...

(1) Very difficult / Very seldom – Difficult / Seldom – Neutral – Easy / Often – Very easy / Very often (5)

How easy or difficult is it for you to...

4. Use the keyboard of a computer (e.g., to type words)?
5. Use the mouse (e.g., to put the cursor in the right field or to click)?
6. Use the buttons or links and hyperlinks on websites?

When you search the Internet for information, how easy or difficult is it for you to ...

7. Make a choice from all the information you find?
8. Use the proper words or search query to find the information you are looking for
9. Find the exact information you are looking for?
10. Decide whether the information is reliable or not?

11. Decide whether the information is written with commercial interests (e.g., by people trying to sell a product)?
12. Check different websites to see whether they provide the same information?
13. Decide if the information you found is applicable to your situation?
14. Apply the information you found in your daily life?
15. Use the information you found to make decisions about your life

When you search the Internet for information, how often does it happen that...

16. You lose track of where you are on a website or the Internet?
17. You do not know how to return to a previous page?
18. You click on something and get to see something different than you expected?

The following items are adapted from the **Search Self-Efficacy Scale (SSE)** by Brennan et al. (2016).

On a scale of 1 to 5, how confident are you that you can ...
(1) Not at all confident – Neither confident nor unconfident – Totally confident (5)

19. Identify the major requirements of the search from the initial statement of the topic.
20. Correctly develop search queries to reflect my requirements.
21. Use special syntax in advanced searching (e.g., AND, OR, NOT).
22. Evaluate the resulting list to monitor the success of my approach.
23. Develop a search query which will retrieve a large number of appropriate articles.
24. Find an adequate number of articles.
25. Find articles similar in quality to those obtained by a professional searcher.
26. Devise a query which will result in a very small percentage of irrelevant items on my list.
27. Efficiently structure my time to complete the task.
28. Develop a focused search query that will retrieve a small number of appropriate articles.
29. Distinguish between relevant and irrelevant articles.

30. Complete the search competently and effectively.
31. Complete the individual steps of the search with little difficulty.
32. Structure my time effectively so that I will finish the search in the allocated time.

B.3 Course Load and Other Engagements

1. How many total weekly hours of coursework are you registered for this semester?
2. How many weekly hours do you anticipate putting in for studying this course?
3. What are your other time commitments, as hours per week? (enter 0 if not applicable)
    - jobs
    - extra-curriculars
    - other
4. Do you hold a position of responsibility (officer / committee member) in any (student) organisation? Yes / No

B.4 Note-taking Strategies

Adapted from *Listening and Note Taking Survey* by (**note-taking-survey-penn-state?**), and *Note Taking Strategies Inventory* by (**note-taking-strategies-umass?**).

For each question, choose the response that best describes your actions (not the one that describes what you think you should be doing). There are no right or wrong answers. In general (not specifically for this course)

1. I take notes using (check all that apply)
    - Paper and Pen / Pencil
    - Laptop / Desktop
    - Tablet with Keyboard
    - Tablet with Stylus / Digital Pen

2. When taking notes on the laptop, I minimize distractions by:

____

On a scale of 1 to 5 . . .

(1) Never – Rarely – Sometimes – Often – Always (5)

3. I read my assignments before I go to lecture.
4. I find lectures interesting and/or challenging.
5. My lecture notes are well organized.
6. I recognize main ideas in lectures.
7. I recognize supporting details of main ideas.
8. I recognize patterns in lectures, e.g., cause-effect, concept-example.
9. My lecture notes are complete.
10. I recognize relationships between lecture and readings.
11. I integrate my lecture notes with my reading notes.
12. I summarize my notes, both lecture and reading, in my own words.
13. I review my notes immediately after class.
14. I conduct weekly reviews of my notes.
15. I edit my notes within 24 hours after class.
16. I take notes
17. I put dates on my notes
18. I makes notes in the margins of the text when I read (on paper / digital medium, e.g. iPad and Apple Pencil)
19. I pause periodically while reviewing notes to summarize or paraphrase the information.
20. I use diagrams in my notes
21. I use different colours when writing notes
22. I create outlines, concept maps or organizational charts of how ideas fit together.
23. I write down questions I want to ask the instructor

24. I reorganize and fill in notes I took in class
25. I put things in my own words
26. I rewrite my notes
27. I use abbreviations in my notes
28. I write out my own descriptions of the main concepts
29. I keep track of things I do not understand and note when they finally become clear and what made that happen
30. I understand my notes
31. I refer back to my notes

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32. How do you organise your notes? ________
33. Have you ever wished that you had written better notes? Why?
    - Yes: ______
    - No: ______
34. How long do you store your notes for?
    1. Till the end of the semester
    2. End of academic year
    3. End of college
    4. Lifelong
    5. Other: ______
35. How do you search for a bit of information in your notes?

B.5 Motivation

Adapted from Intrinsic Motivation Inventory (IMI) (Ryan, 1982). Items will be randomly ordered.

Scoring directions: Score each response from 1 (not at all true) to 5 (very true). Then reverse score the items marked with **(R)**. To do that, subtract the item response from 6, and use the resulting number as the item score. Then, calculate subscale scores by averaging across all the items on that subscale. The subscale scores are then used in the analyses of relevant research questions.

For each of the following statements, please indicate how true it is for you, using the following scale:
(1) not at all true — somewhat true — very true (5)

B.5.1 Interest/Enjoyment

1. I will enjoy taking this course very much.
2. This course will be fun to do.
3. I think this will be a boring course. **(R)**
4. This course will not hold my attention at all. **(R)**
5. I would describe this course as very interesting.
6. I think this course will be quite enjoyable.

B.5.2 Perceived Competence

1. I think I will be pretty good at this course.
2. I think I will be doing pretty well at this course, compared to other students.
3. After working at this course for awhile, I will feel pretty competent.
4. I think I will be satisfied with my performance in this course.
5. I think I am pretty skilled at this course.
6. This is a course that I think would not be able to do very well. **(R)**

B.5.3 Effort/Importance

1. I plan to put a lot of effort into this course.
2. I don't think I will try very hard to do well at this course. **(R)**
3. I will try very hard on this course.
4. It is important to me to do well in this course.
5. I do not plan to put much energy into this course. **(R)**

B.5.4 Value/Usefulness

1. I believe the course and the final project activities could be of some value to me.
2. I think that doing the final project activities is useful for me.
3. I think the final project is important activity to do because it can equip me with skills that are necessary for making ethical decisions in my adult and professional life.
4. I would be willing to do research on the final project topic again because it has some value to me.
5. I think doing the final project activities will help me in my adult and professional life
6. I believe doing the final project activities will be beneficial to me.
7. I think this is an important course.

B.6 Self-regulation

Self-Regulation Questionnaire (SRQ) by (J. M. Brown et al., 1999).

Please answer the following questions by selecting the option that best describes how you are. There are no right or wrong answers. Work quickly and don't think too long about your answers.

(1) Strongly Disagree – Disagree – Neutral – Agree – Strongly Agree (5)

1. I usually keep track of my progress toward my goals.

2. My behavior is not that different from other people's. **(R)**
3. Others tell me that I keep on with things too long. **(R)**
4. I doubt I could change even if I wanted to. **(R)**
5. I have trouble making up my mind about things. **(R)**
6. I get easily distracted from my plans. **(R)**
7. I reward myself for progress toward my goals.
8. I don't notice the effects of my actions until it's too late. **(R)**
9. My behavior is similar to that of my friends. Evaluating
10. It's hard for me to see anything helpful about changing my ways. **(R)**
11. I am able to accomplish goals I set for myself.
12. I put off making decisions. **(R)**
13. I have so many plans that it's hard for me to focus on any one of them. **(R)**
14. I change the way I do things when I see a problem with how things are going.
15. It's hard for me to notice when I've "had enough" (alcohol, food, sweets, internet, social media) **(R)**
16. I think a lot about what other people think of me.
17. I am willing to consider other ways of doing things.
18. If I wanted to change, I am confident that I could do it.
19. When it comes to deciding about a change, I feel overwhelmed by the choices. **(R)**
20. I have trouble following through with things once I've made up my mind to do something. **(R)**
21. I don't seem to learn from my mistakes. **(R)**
22. I'm usually careful not to overdo it when working, eating, drinking, or being on social media.
23. I tend to compare myself with other people.
24. I enjoy a routine, and like things to stay the same. **(R)**
25. I have sought out advice or information about changing.

26. I can come up with lots of ways to change, but it's hard for me to decide which one to use. **(R)**
27. I can stick to a plan that's working well.
28. I usually only have to make a mistake one time in order to learn from it.
29. I don't learn well from punishment. **(R)**
30. I have personal standards, and try to live up to them.
31. I am set in my ways. **(R)**
32. As soon as I see a problem or challenge, I start looking for possible solutions.
33. I have a hard time setting goals for myself. **(R)**
34. I have a lot of willpower.
35. When I'm trying to change something, I pay a lot of attention to how I'm doing.
36. I usually judge what I'm doing by the consequences of my actions.
37. I don't care if I'm different from most people. **(R)**
38. As soon as I see things aren't going right I want to do something about it.
39. There is usually more than one way to accomplish something.
40. I have trouble making plans to help me reach my goals. **(R)**
41. I am able to resist temptation.
42. I set goals for myself and keep track of my progress.
43. Most of the time I don't pay attention to what I'm doing. **(R)**
44. I try to be like people around me.
45. I tend to keep doing the same thing, even when it doesn't work. **(R)**
46. I can usually find several different possibilities when I want to change something.
47. Once I have a goal, I can usually plan how to reach it.
48. I have rules that I stick by no matter what.
49. If I make a resolution to change something, I pay a lot of attention to how I'm doing.
50. Often I don't notice what I'm doing until someone calls it to my attention. **(R)**
51. I think a lot about how I'm doing.
52. Usually I see the need to change before others do.

53. I'm good at finding different ways to get what I want.
54. I usually think before I act.
55. Little problems or distractions throw me off course. **(R)**
56. I feel bad when I don't meet my goals.
57. I learn from my mistakes.
58. I know how I want to be.
59. It bothers me when things aren't the way I want them.
60. I call in others for help when I need it.
61. Before making a decision, I consider what is likely to happen if I do one thing or another.
62. I give up quickly. **(R)**
63. I usually decide to change and hope for the best. **(R)**

Scoring Directions: Score each response from 1 (strongly disagree) to 5 (strongly agree), and calculate the following seven subscale scores by summing the items on that subscale. Items marked **(R)** are reverse-coded (i.e. 1 = strongly agree and 5 = strongly disagree). To do that, subtract the item response from 6, and use the resulting number as the item score.

1. *Receiving relevant information:* 1, 8, 15, 22, 29, 36, 43, 50, 57
2. *Evaluating the information and comparing it to norms:* 2, 9, 16, 23, 30, 37, 44, 51, 58
3. *Triggering change:* 3, 10, 17, 24, 31, 38, 45, 52, 59
4. *Searching for options:* 4, 11, 18, 25, 32, 39, 46, 53, 60
5. *Formulating a plan:* 5, 12, 19, 26, 33, 40, 47, 54, 61
6. *Implementing the plan:* 6, 13, 20, 27, 34, 41, 48, 55, 62
7. *Assessing the plan's effectiveness:* 7, 14, 21, 28, 35, 42, 49, 56, 63

Based on our clinical and college samples, we tentatively recommend the following ranges for interpreting SRQ total scores with the 63-item scale:

- **>= 239**: High (intact) self-regulation capacity (top quartile)

- **214 - 238**: Intermediate (moderate) self-regulation capacity (middle quartiles)
- **<= 213**: Low (impaired) self-regulation capacity (bottom quartile)

B.7 Metacognition

Metacognitive Awareness Inventory (MAI) proposed by Schraw & Dennison (1994) and revised by Terlecki & McMahon (2018).

*Think of yourself as a **learner**. Read each statement carefully, and rate it as it generally applies to you when you are in the role of a learner (student, attending classes, university etc.) Please indicate how true each reason is for you using the following scale:*

Score	Response
1	I **NEVER** do this
2	I do this **infrequently**
3	I do this **inconsistently**
4	I do this **frequently**
5	I **ALWAYS** do this

1. I ask myself periodically if I am meeting my goals.
2. I consider several alternatives to a problem before I answer.
3. I try to use strategies that have worked in the past.
4. I pace myself while learning in order to have enough time.
5. I understand my intellectual strengths and weaknesses.
6. I think about what I really need to learn before I begin a task.
7. I know how well I did once I finish a test.
8. I set specific goals before I begin a task.
9. I slow down when I encounter important information.
10. I know what kind of information is most important to learn.
11. I ask myself if I have considered all options when solving a problem.
12. I am good at organizing information.

13. I consciously focus my attention on important information.
14. I have a specific purpose for each strategy I use.
15. I learn best when I know something about the topic.
16. I know what the teacher expects me to learn.
17. I am good at remembering information.
18. I use different learning strategies depending on the situation.
19. I ask myself if there was an easier way to do things after I finish a task.
20. I have control over how well I learn.
21. I periodically review to help me understand important relationships.
22. I ask myself questions about the material before I begin.
23. I think of several ways to solve a problem and choose the best one.
24. I summarize what I've learned after I finish.
25. I ask others for help when I don't understand something.
26. I can motivate myself to learn when I need to.
27. I am aware of what strategies I use when I study.
28. I find myself analyzing the usefulness of strategies while I study.
29. I use my intellectual strengths to compensate for my weaknesses.
30. I focus on the meaning and significance of new information.
31. I create my own examples to make information more meaningful.
32. I am a good judge of how well I understand something.
33. I find myself using helpful learning strategies automatically.
34. I find myself pausing regularly to check my comprehension.
35. I know when each strategy I use will be most effective.
36. I ask myself how well I accomplish my goals once I'm finished.
37. I draw pictures or diagrams to help me understand while learning.
38. I ask myself if I have considered all options after I solve a problem.
39. I try to translate new information into my own words.
40. I change strategies when I fail to understand.

41. I use the organizational structure of the text to help me learn.
42. I read instructions carefully before I begin a task.
43. I ask myself if what I'm reading is related to what I already know.
44. I reevaluate my assumptions when I get confused.
45. I organize my time to best accomplish my goals.
46. I learn more when I am interested in the topic.
47. I try to break studying down into smaller steps.
48. I focus on overall meaning rather than specifics.
49. I ask myself questions about how well I am doing while I am learning something new.
50. I ask myself if I learned as much as I could have once I finish a task.
51. I stop and go back over new information that is not clear.
52. I stop and reread when I get confused.

Scoring Directions: Score each response from 1 (never) to 5 (always), and calculate the following subscale scores by summing the items on that subscale.

Knowledge about Cognition:

1. *Declarative Knowledge:* 5, 10, 12, 16, 17, 20, 32, 46 (score out of $8 \times 5 = 40$)
2. *Procedural Knowledge:* 3, 14, 27, 33 (score out of $4 \times 5 = 20$)
3. *Conditional Knowledge:* 15, 18, 26, 29, 35 (score out of $5 \times 5 = 25$)

Regulation of Cognition:

1. *Planning:* 4, 6, 8, 22, 23, 42, 45 (score out of $7 \times 5 = 35$)
2. *Information Management Strategies:* 9, 13, 30, 31, 37, 39, 41, 43, 47, 48 (score out of $10 \times 5 = 50$)
3. *Comprehension Monitoring:* 1, 2, 11, 21, 28, 34, 49 (score out of $7 \times 5 = 35$)
4. *Debugging Strategies:* 25, 40, 44, 51, 52 (score out of $5 \times 5 = 25$)
5. *Evaluation:* 7, 19, 24, 36, 38, 50 (score out of $6 \times 5 = 30$) –>

C
Questionnaires for Initial (SES1) and Final (SES3) Sessions

D
SUR2: Midterm Survey

E
SUR3: Exit Survey

F
Variables and Measures

G
Acknowledgements - The PhD Journey

Similar to David Maxwell's thesis.

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