Teachers' Online Searching in Science

by

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Abstract

Given the prevalence of web use by teachers and students and the need for all citizens to be information literate, teachers across curricula are expected to model and develop information literacy and web searching skills within their classrooms. Unfortunately, little is known about how teachers search for and evaluate information online, especially within subject specific contexts. This study investigated teachers' cognition and metacognition related to searching for resources related to science teaching. Eleven secondary science teachers participated in the study. Results highlighted that teachers drew heavily on their science knowledge or past teaching experience when generating search terms. When evaluating resources, teachers considered accuracy of science content, credibility, and the appropriateness of the resource for their teaching context, among other factors. All teachers demonstrated metacognitive knowledge; some exhibited spontaneous metacognitive awareness and control. Finally, there was evidence that participation in the research prompted teachers' metacognitive awareness.

Preface

This thesis is an original work by Carol Brown. The research project of which this thesis is a part, received research ethics approval from the University of Alberta Research Ethics Board, Project Name “Teachers' Metacognition and Online Searching in Science”, No. Pro00038514, June 4, 2013.

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Chapter One

Introduction

This research has developed as a result of my personal experience as a teacher and through my graduate work at the University of Alberta. As a high school science teacher, I frequently utilized the web to locate science content information and teaching resources relevant to my teaching assignment. I recall instances where I experienced challenges locating information; as a result I began to think about the skills I was using in online environments, and how I could improve these skills. I also began to wonder how I could better model online learning for my students.

Through my coursework at the University of Alberta, I explored literature in areas related to science education, education technology, and metacognition (knowledge, control, and awareness of one's thinking). I became interested in studying how teachers search for and evaluate resources online, and considered how the application of a metacognitive framework could provide additional insight in to my questions. Thus, the purpose of this research is to better understand the thought processes used by science teachers while conducting web searches on topics in science, and to shed light on science teachers' knowledge, awareness, and control of their thinking (i.e. their metacognition) related to online searching.

Background

We now live in an information society, where 99% of young Canadians (between grades 4-11) are able to access the internet outside of their schools

(Steeves, 2014b). Online and computer based information searching in school, home and workplace settings is prevalent (Cromley & Azevedo, 2009) and teachers and students frequently utilize the web to support their learning (Perrault, 2007; Quintana, Zhang & Krajcik, 2005). While there are benefits of learning from online sources, there are also additional challenges in comparison to traditional learning settings (such as textbooks). In particular, the complexity and heterogeneity of the web requires that learners be able to integrate relevant content information from multiple websites while also being attentive to information sources and making evaluations of their credibility (Stadtler & Bromme, 2007).

Related to science learning, it has been suggested that media (web based, television and print) has now become the primary source of science information for the majority of adults (McClune & Jarman, 2012). While the internet can provide a wealth of science information to learners of any age, not all information is accurate or credible, thus there is a need for all individuals to develop effective critical thinking and evaluative skills suitable to learning in online contexts. As such, there has been an increasing emphasis on developing citizen's information literacy (IL), which will be defined here as having the skills and associated thought processes necessary to identify an information need and to locate, critically evaluate, and use information from a wide variety of sources in an effective and ethical manner that meets that need (Duke & Ward, 2009; Julien & Barker, 2009; Williams & Wavell, 2007).

Students lack information literacy and online searching skills. There is a consensus within the education community that students need to be information literate in order to be effective lifelong learners, and that schools should work to develop information literacy skills (Eisenberg, Lowe & Spitzer, 2004; Grafstein, 2002). Unfortunately, there is evidence that students and adults are deficient in several areas related to online searching and the evaluation of resources, scientific or otherwise (Adams, 1999; Barranoik, 2001; Branch, 2003a; Eysenbach & Kohler, 2002; Julien & Barker, 2009; Mason & Boldrin, 2008; Metzger, 2007). In particular, students experience challenges with employing effective search strategies (Branch, 2003a; Julien & Barker, 2009), effectively using online tools (Steeves, 2012), generating search terms (Abbas, Norris & Soloway, 2002; Barranoik, 2001) and appropriately citing sources (Barranoik, 2001).

In addition to difficulty experienced when searching for information, there is also evidence that students face challenges with evaluating science information found online (Adams, 1999; Brem, Russell & Weems, 2001; Julien & Barker, 2009). In particular, high school students may possess unsophisticated evaluation skills (Julien & Barker, 2009), rely on surface markers to evaluate credibility, and tend to favor strategies that allow them to expend as little effort as possible (Brem et al., 2001). Further, Mason, Boldrin & Ariasi (2010) argue that "the evaluation of Web resource credibility is not an automatic activity performed by students when they search online information" (p. 68) and that students may need prompting to access higher order (metacognitive) knowledge and strategies to effectively evaluate resources.

The need for teachers to be information literate and metacognitive.

Given the challanges faced by individuals while searching online, it has been widely acknowledged that learners need support and instruction in order to improve their information seeking, and that teachers play an important role in providing this support (Barranoik, 2001; Bilal, 2002; Branch, 2003a; Duke & Ward, 2009; Fidel et al., 1999; Gross & Latham, 2011; Steeves, 2014a). In order to teach web searching skills to students and to enhance their own professional practice, teachers themselves must be information literate, that is they must be "...able to search for, retrieve, and critically evaluate information that empowers their professional practice" (Duke & Ward, 2009, p.254). In addition, teachers must be equipped to model and communicate their thinking and strategies to students, which requires teachers be metacognitive (have knowledge and awareness of their own thinking) (Boekaerts, 1997; Zohar, 2004).

There is some evidence that pre-service and in-service teachers lack adequate information literacy skills (Duke & Ward, 2009); however, little research has been conducted to investigate the thinking employed by teachers within the context of online environments. Even fewer studies have been conducted that focus on teachers' searching within their subject area. Investigation of teachers' thinking related to searching and evaluating science information is of particular importance, for several reasons. First, Brem et al. (2001) highlight that because the web provides almost endless opportunities for re-posting information, it is crucial that individuals "recognize that conduits of information shape the science and create arguments of their own" (p. 210). Second, as mentioned

previously, there is evidence that students struggle to evaluate science information online (Brem et al., 2001; Julien & Barker, 2009) and require support from their teachers. In addition, science teachers must play a role in helping students to develop information literacy; that is, develop knowledge about content and research practices specific to subject areas (such as science), as well as broader skills that apply across disciplines (Grafstein, 2002). Finally, science teachers must be equipped to model and communicate their thinking and strategies to students, which involves metacognition (Thomas, 2012b). Unfortunately, little is known about science teachers' metacognition, overall, and recent literature has called for future research related to science teachers' metacognition (Thomas, 2012b; Zohar & Barziali, 2013). This study aims to begin to address these gaps in the literature by investigating science teachers' cognition and metacognition within the context of online searching. By better understanding how science teachers go about searching for and evaluating information online, we can better understand if teachers are adequately equipped to meet information needs relating to their own professional practice and to lead students in the development of information literacy skills and metacognition.

Purpose and Research Questions

The purpose of this research is to better understand the thought processes used by science teachers while conducting web searches on topics in science and to shed light on science teachers' knowledge, control and awareness of their thinking (i.e. their metacognition) related to online searching. The main research question guiding this study is:

How do science teachers go about searching for and evaluating information online? More specifically, this research aims to elucidate both teachers' cognition and their metacognition; hence the following three sub-questions guide this research:

1. *What are the thought processes science teachers use when searching for science information or resources online?*
2. *What are the thought processes science teachers use when evaluating resources or information from online sources?*
3. *Do science teachers demonstrate knowledge, awareness, and control of their thinking while web searching on science topics? (Are they 'metacognitive' and if so, in what ways?)*

Research Methods

This research employed a qualitative methodology with the aim of obtaining rich data on science teachers' online strategies and associated cognitive and metacognitive processes, while approximating, as closely as possible, teachers typical experience of web searching. Eleven secondary science teachers were recruited; teachers' conducted 30-min web-searches on science topics of their choice related to their teaching. Teachers were asked to think-aloud (Cromley & Azevedo, 2009) during their search. Screen capturing software (Camtasia Studio®) provided a video and audio record of teachers' web searches and accompanying think-aloud statements; browser histories were also saved. Semi-structured interviews were conducted with teachers post-search. These interviews provided an opportunity for teachers to clarify their statements and

thinking during the web search and to provide feedback to the researcher on the initial coding scheme (Connell, 1995; Creswell, 2009). NVivo software was utilized to organize and code data from teachers' web search videos, think-aloud transcripts, and post-search interview transcripts in order to identify themes relating to teachers' behaviors, cognition and metacognition. Some qualitative data was transformed to quantitative data and represented as summary statistics or counts in order to enhance the scrutiny of qualitative data and assist the researcher to derive greater meaning from the teachers' narrative descriptions (Onwuegbuzie & Johnson, 2006).

Definitions

Information literacy. Information literacy is a broad category that encompasses thinking and skills related to identifying an information need and locating, synthesizing, evaluating, and effectively and ethically using information from online environments as well as books, newspapers, radio, television and other media (Chartered Institute of Library and Information Professionals (CILIP), 2004; Eisenberg et al., 2004; Probert, 2009; Williams & Wavell, 2007). In this way, information literacy is seen to encompass other literacies such as visual, media, computer, digital, and network literacy (Eisenberg et al., 2004). While the term *information literacy* is used throughout this paper, it is important to note that this research investigates only one aspect of information literacy: that related to information seeking and resource evaluation related to online contexts.

Overall, there is a lack of coherence relating to the specific skills that an individual must possess in order to be information literate. Information literacy

standards have been outlined by several organizations, such as the Association of College and Research Libraries (ACRL, 2006) and the Association for Teacher-Librarianship in Canada in conjunction with the Canadian School Library Association (Asselin, Branch, & Oberg, 2003). In addition, a number of information literacy models have been developed to provide students and teachers with a framework for the development of information literacy. Such models include (but are not limited to): Kuhlthau's Information Seeking model (Kuhlthau, 1993; 2004), the Research Process Model (Stripling &Pitts, 1988) and the Big6™ Skills for Information Processing Model (Eisenberg & Berkowitz, 1988; 2000). While these models use somewhat different terminology, overall there is "more agreement than disagreement among the models" (Eisenberg et al., 2004, p.43). In particular, through a review of the information literacy standards and models highlighted above, there are several skills that seem to be common among the frameworks. These include having the ability to:

- determine the information need (which involves setting goals, determining the depth and type of information required);
- acquire information (which involves selection and effective use of different sources of information, effective search strategies, refinement of search strategies, and the ability to extract or transfer information from the source);
- critically evaluate information and sources of information (make evaluations of accuracy, relevance, and comprehensiveness, differentiate between fact and opinion, recognize points of view, identify bias);

- ethically and effectively use information (includes synthesizing and communicating information, citation of sources, adherence to laws and regulations relating to information use and privacy); and
- evaluate the process and product of information gathering and use (includes reflecting on successes, failures, and areas of improvement, and identifying future learning needs). (ACRL, 2006; Asselin et al., 2003; Eisenberg et al., 2004; Kuhlthau, 1993; 2004; Stripling &Pitts, 1988)

The information literacy skills outlined here will be revisited throughout Chapter 4, when the results of this study are discussed in relation to information literacy frameworks and previous research related to information literacy and web searching.

Cognition. Cognition, for the purposes of this paper, will be defined generally as an individual's thoughts, beliefs, and internal images (Holden, 2001). An important feature of cognition that distinguishes it from metacognition is that it operates on an object level; cognition involves thinking about people, places, events, ideas, sensations, tasks, or even feelings, whereas metacognition moves above this object level and involves thinking about one's own thinking (Schraw, 1998). For the purposes of this paper, the terms *cognition*, *thinking* and *thought processes* will be used interchangeably to refer to any mental processes at this object level (See Figure 1; Chapter 2).

Metacognition. Although there is no unified definition of metacognition in the literature (Veenman, VanHout-Wolters & Afferbach, 2006), early definitions of metacognition involved knowledge about and regulation of an

individuals' thinking and learning (Flavell, 1979; Brown 1978). While variations in models of metacognition will be discussed in Section 2.4, it is generally accepted that metacognition involves higher order thinking as compared to cognition (Flavell, 1979; Garner & Alexander, 1989; Veenman et al., 2006). Cognition and metacognition, while different constructs, are linked and difficult to separate (Georghiades, 2004).The metacognitive system is simultaneously monitoring and regulating the cognitive system, while being a part of it (Veenman et al., 2006). While some state that metacognition can occur subconsciously (Veenman et al., 2006), my view is that a metacognitive experience is one that is conscious (Flavell, 1979; Thomas 2012a). For the purposes of this research, then, metacognition will be conceptualized as involving conscious, deliberate cognitive monitoring and feedback and will be defined as an individual's knowledge, awareness and control of his or her cognition and cognitive strategies (Flavell, 1979; Garner & Alexander, 1989; Thomas & McRobbie, 2001). The specific model of metacognition utilized in this study will be further elaborated upon in Theoretical Framework subsection.

Significance of the Study

This research has both scholarly and practical significance in relation to science teachers' information literacy and metacognition. First, scholars working in science education have highlighted a need for a better understanding of teachers' online search strategies and information literacy skills (Julien & Barker, 2009; Perrault, 2007) and science teachers' metacognition (Thomas, 2012b). This area of research is of particular relevance because of the frequency of science

teachers' use of the internet to locate teaching resources (Perrault, 2007), to support their teaching within their classroom (Recker et al., 2007) and due to the expectation that science teachers play a role in the development of students' information literacy skills (Julien & Barker, 2009) and metacognition (Thomas, 2012b). In order to effectively undertake these tasks, science teachers must be information literate and metacognitive; while some may assume this is the case, there is little scholarly research to support or refute this assumption. Currently, there are a limited number of studies that address teachers' online searching (see Perrault, 2007; Recker, Dorward & Nelson, 2004) and fewer still that employ a metacognitive framework (see Hill & Hannafin, 1996). Thus, this research offers the potential to begin to address this gap in the literature.

While the findings of this study could be significant for scholars working in fields related to science education, information literacy, and metacognition, they could also be utilized for professional development and teacher training programs related to effective web searching skills in science. An increased understanding of these skills could aid teachers in their own searches for science information and resources (Mardis, ElBasri, Norton & Newsum, 2012) and in becoming more effective cognitive and metacognitive models for students. This is significant for students because:

> Unless teachers are knowledgeable about the thinking processes required to learn science, can and do make expectations and required cognitive processes explicit for students, and model those cognitive processes, then

> the chances of students learning and managing those processes are diminished. (Thomas, 2012b, pp. 35/36)

Thus, the findings of this research offer the potential to inform future practice that could benefit both teachers and students.

Chapter Two

Literature Review

The purpose of this chapter is to situate this study within the broader context of science education research, specifically drawing on literature related to the areas of science education, information literacy, and metacognition. The first section will draw on relevant literature and applicable curriculum documents to describe why the science classroom is a suitable environment for the instruction of web information literacy skills and the development of associated metacognition. The following section will outline the role of teachers in developing students' information seeking and evaluative strategies. Next, I will identify what is currently known about teachers' information literacy, online search strategies and metacognition. Finally, the section entitled Theoretical Framework will describe the specific metacognitive framework that will be utilized in this study and outline the relationship between metacognition and learning.

Information Literacy, Science Literacy, and Metacognition: Intersections in the Science Classroom

Schools are seen as important environments for the development of information literacy skills in students (Smith, 2013; Williams & Wavell, 2007) and it has been widely acknowledged that these skills must be developed across all curricula (Allen, 2007; Eisenberg, Lowe & Spitzer, 2004; Grafstein, 2002; Julien & Barker, 2009). In particular, current models of information literacy extend beyond generic technical skills required for locating information (such as

how to use a web browser) and also require individuals to understand, evaluate and synthesize various types of information; thus information literacy instruction must occur within subject disciplines (Grafstein, 2002). That is, this research is conducted from the perspective that developing the thinking and skills required to locate, understand and evaluate science information (from online or other sources) are best learned within the science classroom. Thus, similarly to the perspective of Grafstein, this work:

> ...views IL as defining an independent and critical way of thinking and reasoning about disciplines, and ... argues that imparting IL skills to students involves equipping them with both knowledge about the subject-specific content and research practices of particular disciplines, as well as the broader, process-based principles of research and information retrieval that apply generally across disciplines. (p. 197)

Additional evidence that science classrooms provide an appropriate context for the instruction of information literacy skills is provided by Julien & Barker (2009), who highlighted similarities between information literacy and science literacy skills. For example, while there is no unified consensus on a complete set of characteristics possessed by a scientifically literate individual, there is general agreement that higher order, metacognitive thinking skills and the ability to locate and critically evaluate science information play an important role (Hurd, 1998; Leou, Abder, Riordan & Zoller, 2006). Further, encouraging students to partake in online research and inquiry can enhance students' science learning and understanding of the nature of science (Julien & Barker, 2009).

Julien and Barker assert that "...information literacy is embedded in the principles and processes of science and thus by highlighting and including such tasks in science inquiry in the classroom, a much more 'authentic' experience of science can be provided" (p. 1).

In addition to arguments found in educational literature for the inclusion of information literacy instruction within science classrooms, the curriculum documents (Programs of Study) for the teachers participating in this research also emphasize the development of information literacy skills. The Alberta science curriculum (Alberta Education, 2007a) emphasizes information literacy in that it requires that high school students be able to[1]:

- research, integrate and synthesize information from various print and electronic sources regarding a scientific question;
- research, integrate and synthesize information from various print and electronic sources relevant to a practical problem;
- plan complex searches for information, using a wide variety of electronic and print sources;
- assess and develop appropriate processes for collecting relevant data and information about science and technology related issues;
- research, integrate and synthesize information from various print and electronic sources relevant to a given question, problem or issue;

[1] These outcomes were drawn from the Biology 20-30 Program of Studies, however, the same statements are found in other Alberta Programs of Study, including: Chemistry 20-30; Physics 20-30; Science 20-30 and Science 10, 14-24.

- select information and gather evidence from appropriate sources and evaluate search strategies; and
- apply given criteria for evaluating evidence and assess the authority, reliability, scientific accuracy and validity of sources of information. (p. 8 - 10)

In addition to the skills outlined in science curricula, Alberta Education (2008) has outlined a list of outcomes related to information technology and communication skills (ICT). These outcomes are to be addressed across curricula and therefore are also relevant to the context of science classrooms. Overall, considering both scholarly literature and the curriculum documents that are mandated within this province, there is significant evidence that students' ability to find, evaluate and effectively utilize information found online should be developed within science classrooms in Alberta; as such, science teachers play an important role in this process, as will be discussed next.

The Role of Teachers in Developing Students' Information Seeking and Evaluative Strategies

While some teachers may assume that information literacy skills will be passively acquired by students (Smith, 2013; Williams & Wavell, 2007), there is considerable evidence that students need support and instruction on web searching skills and evaluative strategies in order to improve their information seeking (Barranoik, 2001; Bilal, 2002; Branch, 2003a; Fidel et al., 1999; Gross & Latham, 2011; Stadtler & Bromme, 2007). For example, in a study of grade 7 students seeking information on topics of their choice, Bilal (2002) found that most

children selected topics that were very broad and needed mediation to help them identify their true information need. Further, "topic mediation [was] essential to assist children in formulating a clear focus to pursue" (Bilal, 2002, p. 1181).

In a study with Canadian junior high school students, Branch (2003a) found that instruction (by teachers and school librarians) was key to improving students' information seeking. In addition, Branch found that providing emotional support to students was important to their success, as students often felt discouraged or frustrated during their online searches, especially when they could not find sufficient information on their topic or if their search terms provided too many results. Overall, Branch concluded that "...there is a need for teachers and school librarians to work with junior high students to help them learn to access information efficiently and effectively" (p.56).

Similar findings have been stated related to senior high school students in Canada. For example, Barranoik (2001) conducted a study with high school students in Alberta and found that students struggled with many aspects of information searching, such as planning their search, using search terms, and analyzing websites. Students also benefitted from assistance from teachers or teacher librarians. Barranoik highlighted that: "educators and library information specialists working with students in the area of research need to understand and use appropriate intervention and motivational strategies to ensure that students gain understanding and construct meaning and do not merely regurgitate data" (p. 29). In addition, Barranoik found that students working on a science research project were more likely to consult their science teacher for help than a teacher

librarian; the author felt this was perhaps due to students' perception that science requires specialized knowledge. While further research is required to validate this claim, Barranoik's study highlights that teachers and researchers "cannot assume that students have computer and research skills" (p. 43) and that teachers play a critical role in supporting students to develop their thinking and strategies related to online searching.

More recent research supports the findings of the previous studies. For example, the *Young Canadians in a Wired World* study highlighted that Canadian teachers' believe that "access to networked technologies has not made their students better learners. In spite of the fact that young people demonstrate a facility with online tools, many students lack the skills they need to use those tools effectively for learning" (Steeves, 2012, p. 9). This report, as well as more recent work (Steeves, 2014a) highlights that teachers play an important role in helping Canadian students gain skills in online environments. In particular, students reported that teachers play an important role in helping them learn to search for information and in recommending or confirming reliable sources of information (Steeves, 2014a).

Finally, in a study with undergraduate students conducting online searches, Stadtler and Bromme (2007) found that, when students received metacognitive prompts related to monitoring and evaluation, participants acquired more factual knowledge on the topic they were searching. While more research needs to be conducted to determine how metacognitive interventions would influence younger students' web searching, what is clear from the literature

described above is that students require and benefit from teacher[2] support related to a variety of tasks and strategies required for conducting effective web searches.

Research on Teachers' Information Literacy, Online Searching, and Metacognition

In order to effectively locate resources for their teaching and assist students to develop their online searching skills, teachers must be information literate, that is, they must be: "...able to search for, retrieve, and critically evaluate information that empowers their professional practice" (Duke & Ward, 2009, p.254). In addition, teachers must be equipped to model and communicate their thinking and strategies to students (Boekaerts, 1997; Zohar, 2004). While there is no research that specifically investigates science teachers' cognition and metacognition in online environments, there is evidence to suggest that teachers may not have a complete conception of information literacy (Williams & Wavell, 2007). In addition, teachers may experience several challenges in searching for and evaluating information (Duke & Ward, 2009; Williams & Coles, 2007a; 2007b; Wang, 2007). Finally, research indicates that teachers are not always effective at monitoring, evaluating, or explaining their thinking (Kozulin, 2005; Zohar, 2004). Each of these areas will be discussed, in turn.

Teachers' conceptions of information literacy. While examining teachers' conceptions of information literacy is not a specific focus of this study, it is assumed that teachers' conceptions and beliefs about information literacy

[2] It has been argued that collaborative efforts of teachers and school librarians is required for effective integration of information literacy concepts and skills in the K-12 setting (Duke & Ward, 2009) but as teacher librarians are not the focus of this research, these arguments have been omitted from this work. Similarly, the role of parents in instruction of information literacy skills has been omitted from this work.

influence both their online searching and their teaching (Smith, 2013; Williams & Coles, 2007b), thus they are of relevance here. Studies of teachers' conceptions of information literacy highlight that while there is evidence that teachers see the development of students' information literacy skills as an important priority, teachers may be unfamiliar with the term information literacy or how to define it (Smith, 2013; Williams & Wavell, 2007). Further, Williams and Wavell found that in some areas, such as:

> the ability to use and evaluate sources of information, apply a range of skills, and develop as independent learners, teachers' conceptions of information literacy showed considerable overlap with the kinds of models and frameworks[3] which have been developed by information professionals. However, a number of facets of information literacy which have been represented in previous information literacy models were not discussed or developed to any significant extent by teachers in this study. (p. 207)

In particular, the authors found that teachers failed to identify processes related to information organization and management (such as record taking or storing information) and to broad ethical considerations (highlighting relationships between information, values and society). In addition, teachers viewed basic linguistic understanding as being part of information literacy but considered knowledge development as separate, which was not consistent with information literacy models (Williams & Wavell, 2007). Overall, Williams and Wavell's

[3] The authors were referring to (among others): the Big6 Model (Eisenberg & Berkowitz, 1988; 2000), the model by Kuhlthau (2004); and the CILIP definition of information literacy (CILIP; 2004), as highlighted in Chapter 1.

research in the UK and Smith's research in Alberta highlights that while teachers may be able to articulate a number of strategies and thought processes that could be undertaken by an information literate individual, they may not be working from a complete model of information literacy.

Finally, studies of teachers' conceptions of information literacy also highlight several barriers to teachers' instruction of information literacy skills. First, teachers may assume that students will acquire information literacy skills without explicit instruction (Smith, 2013; Williams & Wavell, 2007), despite evidence that this is not the case (Barranoik, 2001; Branch, 2003a). In addition, teachers may not feel confident or prepared to teach information literacy skills to students. For example, Williams and Wavell (2007) reported that all teachers in their study "found it difficult to see how they could influence the cognitive elements associated with information literacy" (p. 205). Similarly, Smith (2013) found that teachers' "struggles to identify and clearly articulate means of incorporating IL activities... indicate that they are not consciously considering aspects of IL" (p. 220). Lack of time was cited as another barrier teachers faced to the implementation of information literacy instruction, given the curricular constraints and other demands on teachers' time (Mardis et al., 2012; Williams & Wavell, 2007). Finally, that teachers may lack adequate information literacy skills (Duke & Ward, 2009; Williams & Coles, 2007b) may be seen as another barrier to effective instruction, as will be described in more detail in the following section.

Teachers' information literacy and web searching skills in practice.

While the previous section focused on teachers' conceptions of information literacy models and barriers to information literacy instruction, this section seeks to highlight the major findings of research related to teachers' information literacy and web searching skills in practice. Overall, previous research provides evidence that teachers' may lack information literacy skills (Duke & Ward, 2009; Williams & Coles, 2007b; Wang, 2007), but also highlights that there is considerable variation in the strategies teachers employ in online environments while locating and selecting resources related to their teaching (Hill & Hannafin, 1996; Recker et al., 2004). In general, however, relatively little is known about how teachers think or behave in online environments.

Teachers' information literacy. There are an increasing number of studies related to teachers' information literacy that offer insight on the challenges faced by teachers when searching for, evaluating, and effectively utilizing resources. For example, there is evidence that teachers may lack effective searching and evaluative skills and have naive perceptions relating to their abilities (Wang, 2007). In the study by Wang, approximately 90% of pre-service teachers reported that they could identify key words and narrow down their searches but 40% of the teachers experienced challenges in identifying their information needs. In addition, 80% of the teachers felt they had sufficient knowledge to critically evaluate information online, however, less than one third of teachers were familiar with evaluation guidelines for web resources (Wang, 2007). There is also concern that teachers may not be accessing quality resources, as Williams and Coles

(2007b) found that teachers did not typically access scholarly education literature or research when they were searching for information to inform and improve their teaching practice. The authors concluded that:

> Teachers' use of and knowledge of sources to support evidence-based practice is limited in range. [T]he reliance on informal sources and/or more general sources of information does little to provide the kind of knowledge base needed for informed judgements about information or for the building or self-confidence in finding and using information. (p. 202)

Several other studies have reported that pre-service teachers may need assistance developing information literacy knowledge and skills and in integrating them into their teaching practice, but that these skills can be improved through training (Asselin, 2000; Branch, 2003b). For example, Branch found that pre-service teachers initially failed to connect information literacy and information communication technology (ICT) skills to their teaching contexts, prior to partaking in a class that explored topics related to information literacy and resource based learning. Upon completion of the course, however, teachers' understandings of information literacy improved and teachers were better able to see ways that information literacy skills could be integrated within their classrooms (Branch, 2003b). Finally, in a meta-synthesis of research related to teachers' information literacy, Duke and Ward (2009) concluded that:

> ...pre-service and in-service teachers often lack adequate information literacy skills; many teachers are unable to locate, critically evaluate, and effectively use educational research that might strengthen their

> instructional practices; many teachers are unprepared to teach information literacy concepts and research strategies to their own P-12 students. (p. 251)

Thus, based on research relating to teachers' information literacy, there is significant evidence to indicate that teachers have several areas of deficit related to their general information searching and evaluative skills. Subsequent discussion will focus on research that explores teachers' behaviors and thinking while searching for information in online environments.

Research relating to teachers' web searching. In contrast to the studies described above, which looked generally at research on teachers' information literacy, this section will focus specifically on research relating to teachers' search strategies and evaluative skills within online environments. For example, Recker et al. (2004) investigated science and math teachers' search strategies and selection criteria when looking for digital resources. Recker et al. found that teachers used multiple search strategies, often starting with a broad focus and then later narrowing their searches; and at other times moved directly to teacher-oriented websites that were organized according to topic and grade level. Teachers in this study "preferred sites that were dependable, in particular well-known sites that provided collections of learning resources and links" (Recker et al., 2004, p. 98) and also valued resources that were either developed by teachers or acknowledged the needs of teachers. When selecting resources, teachers preferred smaller-grained resources that could be easily incorporated into their teaching context over fully developed lesson plans. Teachers also identified the following

criteria for selecting particular resources: "age appropriate, current, accurate, and related to state core concepts in the curriculum.... simple, with clear instructions that provided an appropriate overview of the topic that students would find engaging and interactive" (Recker et al., 2004, p. 99).

Overall, while the study by Recker et al. (2004) provides some meaningful insight on teachers' online search strategies and evaluation criteria, it relied on teachers' self reports of their past behavior as provided through interviews and surveys, thus it cannot be determined whether or not the findings are representative of the actual behaviors and thinking undertaken by teachers during online searches. Further, the study by Recker et al. did not examine teachers' thinking in relation to why they used particular search strategies or how they determined if a resource was age appropriate, current, accurate, engaging or interactive.

Finally, in an exploratory study by Hill and Hannafin (1996), the authors investigated factors influencing the strategies used by teachers while navigating the web. Four teachers were recruited; data was generated through pre and post surveys of teachers' metacognitive, system, and subject knowledge and through think-aloud audio and video recordings of web searches, audit trails of web navigation, and post-search interviews. Results indicated that teachers used a variety of strategies to seek information and that search processes were influenced by teachers' level of: disorientation, perceived self-efficacy, metacognitive knowledge, system knowledge, and subject knowledge (Hill & Hannafin, 1996). Of the three prior knowledge areas examined by the authors, metacognitive

knowledge was seen to most influence strategies used by teachers and correspond to success in system use. In addition, Hill and Hannafin found that teachers with lower subject knowledge engaged in more basic search strategies, but that teachers' system knowledge had a stronger influence on strategies used than did subject knowledge.

Overall, while the study by Hill and Hannafin (1996) is dated, it provides considerable insight on factors that may influence teachers' online searching. In addition, it highlights that metacognition may play a significant role in the search processes employed by teachers in online environments, which has also been found in studies of non-teachers (Stadtler & Bromme, 2007; Quintana et al., 2005). While I have been unable to locate any additional studies that examine teachers' cognition and metacognition within the context of online searching, there is some research related to teachers' metacognition more generally, as will be described next.

Research on teachers' metacognition. Given that student metacognition can be enhanced through both explicit instruction and teacher modeling (Boekaerts, 1997; Schraw, 1998; Thomas, 2012a; Veenman et al., 2006), the specific qualities teachers require to create metacognitively oriented learning environments has been paid some, albeit limited, attention in the educational literature (Thomas, 2012b). Boekaerts (1997) and Zohar (2004) highlight that, in order to enhance metacognition in students, teachers must themselves possess a repertoire of adaptive metacognitive knowledge and skills and be able to communicate their thinking. Within the context of science, teachers require

cognitive and metacognitive knowledge and skills related to learning outcomes centered on conceptual understanding and modes of inquiry specific to science (Georghiades, 2004; Thomas 2012b). However, while there are expectations of what teachers should know and be able to do in relation to their cognition and metacognition, few studies have been conducted to provide insight on the thinking teachers actually employ (Georghiades, 2004; Thomas, 2012b; Zohar & Barzilai, 2013). This area may have been neglected due to a preoccupation with pedagogical interventions that focus on enhancing student metacognition, or due to the assumption that teachers are already knowledgeable about their own cognition and metacognition (Thomas, 2012b).

What limited research exists on teachers' metacognition throws in to question whether teachers' are as knowledgeable about their thought processes as has previously been assumed (Kozulin, 2005; Leou et al., 2006; Thomas, 2012b). Kozulin (2005) found that teachers completing cognitive problem solving activities had difficulty reflecting on and expressing their thinking, even when they could effectively complete cognitive tasks. Similarly, Zohar (1999; 2004) found a discrepancy between science teachers' procedural knowledge and declarative metacognitive knowledge. That is, teachers could solve problems, draw conclusions, and design experiments and learning materials, but had difficulty explaining their thinking related to these tasks. As such, the major finding from this work was that teachers' declarative metacognitive knowledge of thinking, "was found to be unsatisfactory for the purpose of teaching higher order thinking in science classrooms" (Zohar, 1999, p. 426).

Leou et al. (2006) conducted a study of teachers' metacognitive and higher order thinking strategies; teachers were assessed pre- and post-completion of a science teacher professional development course aimed at enhancing question asking (QA), problem solving (PS), and conceptualization of fundamental concepts in science (CFC). The overall findings of this study indicated that teachers initially experienced some difficulty related to engaging in higher order thinking (QA, PS, and CFC) and reflecting upon their own thinking. As a result of the professional development course, however, teachers undertook self-assessment and reflected on their thinking, which helped them to develop metacognitive knowledge and awareness and to understand the importance of metacognition in relation to their science teaching (Leou et al., 2006).

Finally, in his literature review on science teachers' metacognition, Thomas (2012b) concluded that teachers' metacognitive knowledge may be unsatisfactory for the purpose of enhancing students' metacognition and that teachers have difficulty articulating their thinking processes. While the studies mentioned above support these conclusions, it is clear that more research is required to shed light on the nature of teachers' metacognition. In addition, it should be noted that a more recent review of literature related to science education and metacognition, conducted by Zohar and Barziali (2013), supported Thomas' call for future research on pre- and in-service science teachers' metacognition.

Theoretical Framework

As previously identified, metacognition, for the purposes of this study, will be defined as knowledge, awareness, and conscious control of one's thinking

(Flavell, 1979; Garner & Alexander, 1989; Thomas 2012b). The following sections will further describe the theoretical framework employed in this study by defining and providing examples of metacognitive knowledge, awareness, and control and will highlight the relationship between metacognition and learning.

Metacognitive knowledge. Metacognitive knowledge involves knowledge about cognition and cognitive processes and can be divided in to declarative, procedural and conditional categories (Schraw, 1998; Thomas & McRobbie, 2001). Declarative metacognitive knowledge involves knowledge about cognitive strategies, beliefs about one's self or others as learners, and beliefs about particular tasks (Schraw, 1998; Thomas & McRobbie, 2001). For example, having knowledge that 'skimming for key-words is a reading strategy', or that 'I am good at memorizing' are examples of declarative metacognitive knowledge. Procedural metacognitive knowledge includes information about how to perform cognitive tasks; that is, the processes used (Schraw, 1998; Thomas & McRobbie, 2001). Examples of procedural metacognitive knowledge might include understanding how to chunk new information (Schraw, 1998) or how to generate mnemonics to aid in memorization (Thomas, 2012b). Finally, conditional metacognitive knowledge involves knowledge of when or why declarative or procedural knowledge should be used (Schraw, 1998; Thomas & McRobbie, 2001). Examples of conditional metacognitive knowledge would include understanding when and why it might be appropriate to use a chunking strategy; to skim for keywords, or to memorize information.

Finally, it should be noted that declarative, procedural, and conditional metacognitive knowledge interact with one another and are not fundamentally different from other types of knowledge (Flavell, 1979). There is also evidence to indicate that metacognitive knowledge can be specific to a particular domain or task (Veenman et al., 2006), or can be more generalized in nature (Schraw, 1998). Metacognitive knowledge is also related to metacognitive awareness and control, which will be described next.

Metacognitive awareness and control. Metacognitive awareness is the intentional monitoring of one's cognitive processes and is similar to Schraw's (1998) *monitoring*, which involves "on-line awareness of comprehension and task performance" (p. 115). Metacognitive control involves the regulation of one's cognition (Alexander, Carr, & Schwanenflulgel, 1995). As with metacognitive knowledge, the extent of an individual's metacognitive awareness and control can vary between tasks or domains, or can transfer across contexts (Schraw, 1998; Thomas, Anderson & Nashon, 2008; Veenman et al., 2006). When considered together, these components of metacognition are conceptualized by the author as a feedback mechanism whereby an individual gathers information about the cognitive process being used, reflects on this process and its effectiveness for the given task (which involves metacognitive awareness draws on metacognitive knowledge), and then exerts metacognitive control through the individual's choice to continue utilizing the cognitive process, make modifications, or abandon the process altogether. For example, if an individual recognized they were not understanding a particular passage they had just read, then decided to re-read the

passage and 'chunk' the information, they would be demonstrating both metacognitive awareness and metacognitive control and would have also drawn on their metacognitive knowledge of strategies they could use, such as 'chunking'. A visual representation of the relationship between cognition and metacognition as conceptualized for this research is identified in Figure 1.

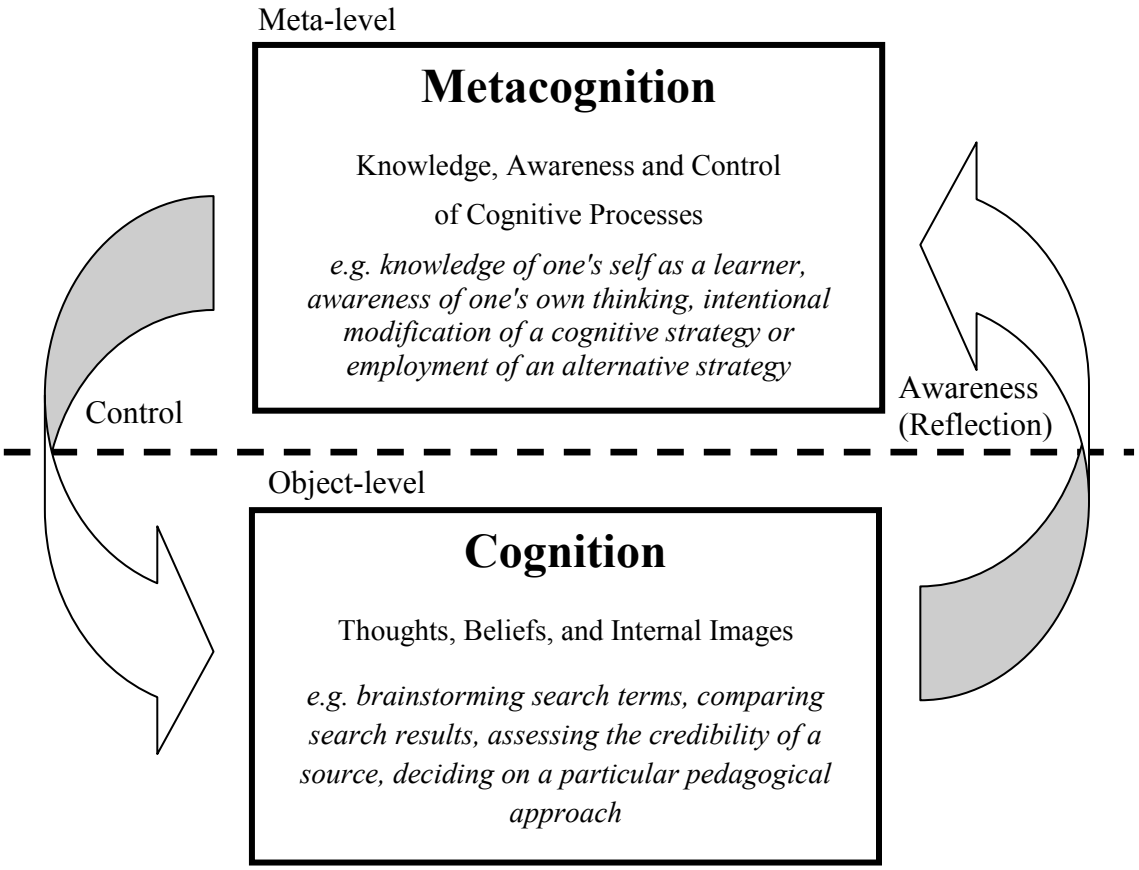

Figure 1. Relationship between cognition and metacognition. Adapted from Nelson and Narens, (1994); Thomas, (2012b).

The relationship between metacognition and learning. While learning is a complex and multi-faceted phenomenon, the role of metacognition in enhancing learning has been identified in educational literature for decades (Flavell, 1979; Brown 1978; Brown, 1994; Thomas & McRobbie, 2001; Thomas,

2012a). When learners are viewed as actively constructing rather than passively receiving knowledge, a learner's knowledge and awareness of their thinking becomes important (Brown, 1994). As Brown notes:

> A great deal of academic learning ... is active, strategic, self conscious, self motivated, and purposeful. Effective learners operate best when they have insight in to their own strengths and weaknesses and access to their own repertoires of strategies for learning. (p. 9)

Generally speaking, there is evidence that individuals who possess adaptive metacognitive knowledge and skills experience learning benefits, both within traditional educational settings (Boekaerts, 1997) and outside them (Glaser & Chi, 1988).

For tasks related to online learning, there is evidence that effective web searches require higher order cognitive and metacognitive thinking skills (Brem & Boyes, 2000; Brem et al., 2001; Mason & Boldrin, 2008; Mason et al., 2010; Quintana et al., 2005; Stadtler & Bromme, 2007). For example, Stadtler and Bromme conducted a quasi-experimental study in which non-expert adults conducted web searches on medical topics. Participants were randomly assigned to four groups that received either monitoring[4] or evaluative[5] metacognitive prompts, both type of prompts, or no prompts (control group). The results of the study indicate that participants who received evaluation prompts had greater post-search knowledge of sources and could identify source information more

[4] Monitoring prompts asked participants to focus on what they currently know and need to know about the topic, and how well they understood w hat they were reading.
[5] Evaluative prompts asked participants to focus on the source of information, such as the author's credentials, biases present, and their confidence in the information.

frequently when making credibility judgments, when compared to the control group. In addition, participants who received monitoring prompts acquired significantly more knowledge during their searches and performed slightly better on comprehension tests, compared to the control group (Stadtler & Bromme, 2007). Overall, the study by Stadtler and Bromme highlights that metacognition plays a role in the evaluation of information and acquisition of knowledge in online environments.

Mason et al. (2010) investigated the relationships between grade eight students' prior knowledge of a topic, study approach, beliefs about science, and metacognition within the context of an online searching task. The findings of this study provided some evidence "that high self-regulation in learning from multiple online sources may also help the activation of more sophisticated beliefs in evaluating the knowledge at hand" (p. 85). This study built on previous work by the authors (see Mason & Boldrin, 2008) which highlighted that students at different levels (undergraduate, high school, and middle school) spontaneously express metacognition in varying levels of sophistication during their online searches, with younger students demonstrating rather naive criteria of knowledge justification, overall.

Brem et al. (2001) conducted a study with grade 9, 11, and 12 students in which students were introduced to evaluation criteria for online information, then asked to visit six science websites. The websites were pre-selected by the researchers to represent hoaxes, weak sincere sites or strong sincere sites. The authors found that students experienced several challenges while evaluating the

websites, including difficulty assessing accuracy, credibility, and reasonableness of sites. Students also demonstrated a lack of metacognitive awareness in relation to how they made their assessments (Brem et al., 2001). These findings are supported by the work of Quintana et al. (2005), who suggest that learners conducting online inquiry face three metacognitive challenges: difficulty with task understanding and planning, monitoring and regulation, and reflection. Overall, these studies provide evidence that individuals face numerous challenges while searching online and that adaptive metacognition is related to the effectiveness of online searches (Mason et al., 2010; Quintana et al., 2005; Stadtler & Bromme, 2007).

Summary

This chapter has highlighted the necessity for science teachers to have effective online searching and evaluative skills. These skills are essential such that teachers can be critical consumers of information related to their own teaching practice and so they can model and instruct these skills and thinking processes within their classrooms. While there is evidence that both students and teachers lack information literacy skills (Adams, 1999; Julien & Barker, 2009; Duke & Ward, 2009; Wang, 2007) and that teachers may not be able to identify or explain their thinking (Kozulin, 2005; Leou et al., 2006), relatively little is known about the strategies and thinking teachers employ within online environments. Few studies have actually observed teachers during their online searches and even fewer within a subject specific context. This research aims to begin to address that

gap in the literature by investigating science teachers' cognition and metacognition within online environments.

Chapter Three

Methodology

Qualitative Research

Qualitative research is "a means for exploring and understanding the meaning individuals or groups ascribe to a social or human problem" (Creswell, 2009, p. 4). This form of research is appropriate when there is a need for a complex understanding of an issue or problem, especially one that cannot be explained through quantitative means (Creswell, 2007). Further, qualitative research focuses on representing the views and perspectives of people involved in the study and aims to provide insight in to existing or emerging concepts that may help explain human behavior (Yin, 2011). As such, a qualitative methodology is well suited to this study, because this research attempts to explore and describe complex phenomenon (teachers' cognition and metacognition) and represent the diversity in thinking expressed by participants rather than attempting to 'control out' conditions or imply correlation or causation (Yin, 2011).

Though a single, formalized qualitative research methodology does not exist (Yin, 2011), there are methodological practices that are common for qualitative research. Yin recommends flexible research designs that include multiple sources of evidence rather than reliance on a single source, which allows for triangulation of data from different sources and adds to the credibility and trustworthiness of the study. During data analysis, qualitative research requires the researcher to interpret data in order to move from particulars to general themes, with a focus on rendering the complexity of a situation (Creswell, 2007).

Through analysis by the researcher, qualitative research avoids becoming a chronicle of everyday events or experiences; rather "it is driven by a desire to explain these events, through existing or emerging concepts" (Yin, 2011, p. 8). Finally, while there are multiple variations of qualitative research, such as grounded theory, ethnography, case study, phenomenological research, narrative inquiry, and others (Creswell, 2009), Yin (2011) highlights that "strong, if not exemplary, studies can be conducted under the general label of 'qualitative research' or 'field-based study' without resorting to any of the variations" (p. 16). Thus, this study will be described generally as a qualitative study. The following sections will describe the implications of previous research on this study's design and will provide more detail about the research design and methods utilized in this study.

Methodological Implications of Previous Research

This section seeks to describe how the methodologies employed in previous studies with similar research questions and goals informed the research design of this study. In particular, previous studies related to cognition and metacognition related to web searching emphasize the importance of acknowledging contextual factors and employing multiple methods of data collection, including both on-line (i.e. measurement occurs in real time) and off-line (i.e. measurement occurs before or after the task) methods. Each of these areas will be discussed, in turn.

Consideration of context. Research on individuals' search behavior, cognition and metacognition within online environments acknowledge that there

are multiple contextual factors that play a role in an individual's search (Hill & Hannafin, 1996; Williams & Coles, 2007b) and that researchers must carefully consider these factors when designing their study (Connell, 1995; Hofer, 2004). In particular, qualitative methodologies that gather a broad range of data are preferable to quantitative approaches, because searching is performed within a context. Indeed, "systems that isolate the search task and concentrate on mechanical aspects of searching... to the exclusion of intellectual aspects... will mask important connections to the larger picture of information production, storage, retrieval and dissemination" (Connell, 1995, p. 516). In addition, Hofer (2004) highlights that researchers studying individual's online searching should design their study with an aim to "replicate as closely as possible a typical search process" (p. 52) in order to provide a more accurate representation of an individuals' typical thinking and actions than would be derived from a contrived research scenario. Hofer's approach arose from her belief that research methodologies should be grounded in the context of learners' actual experience, which is also supported by other work that highlights the contextual nature of cognition and metacognition (Zohar & Barzilai, 2013).

Multiple methods of data collection: On-line and off-line methods. Research methods are "specific strategies, instruments and procedures employed in the procurement, analysis and reporting of data within a research methodology" (Anderson, Nashon, & Thomas, 2009, p. 182). Related to research on cognition and metacognition, it is important to note that cognition and metacognition cannot be directly observed in an individual, therefore “all measures of metacognition

involve different degrees of inference" (Thomas, 2012a, p. 135). In addition, there is no unified consensus on methods best employed for the measurement of cognition and metacognition, as the extent to which different scholars accept higher or lower degrees of inference varies (Thomas, 2012a). In addition, the appropriateness of a specific method is dependent on the constructs being measured (Schraw, 2009).

Most generally, methods aimed at measuring metacognition can be broadly categorized as either off-line or on-line (Veenman et al., 2006). "Off-line methods are presented either *before* or *after* a task performance, whereas on-line assessments are obtained *during* task performance" (Veenman et al., 2006, p.9). Past research focused on the measurement of cognition and metacognition has employed off-line measures such as surveys, (Leou et al., 2006; Thomas, 2006), interviews and stimulated recall (Anderson et al., 2009) and on-line measures such as think-aloud protocols (Hill & Hannafin, 1996; Hofer, 2004), eye-movement recordings (Kinnunen & Vauras, 1995), and observations (Cromley & Azevedo, 2009; Hill & Hannafin, 1996). Of the two categories of methods, Veenman et al. (2006) suggest that on-line methods are better predictors of learning performance; however, both on-line and off-line methods have benefits and drawbacks which must be considered in relation to the context of the research questions and goals.

In order to balance the drawbacks of different methods of data collection (on-line or off-line) and to enhance the credibility of findings, it is recommended that researchers employ multiple methods of data collection in studies of

metacognition (Garner & Alexander, 1989; Veenman et al., 2006). When considering studies of cognition and metacognition in online environments, the use of multiple methods is also a common feature of research designs (see Brem et al., 2001; Connell, 1995; Cromley & Azevedo, 2009; Hill & Hannafin, 1996; Hofer, 2004; Mason et al., 2010). [6] In general, it has been acknowledged that the use of multiple methods will "result in a more accurate and more complete representation of expertise" (Connell, 1995, p. 508) than a single means could provide.

In addition, it should be noted that when employing multiple methods, researchers tend to use at least one open-ended method of data collection (such as think-aloud protocols and / or interviews), in order to obtain a more complete picture of an individual's unique repertoire of cognitive and metacognitive knowledge and skills (Connell, 1995; Cromley & Azevedo, 2009; Hill & Hannafin 1996; Hofer, 2004). In addition, Hofer (2004) argues that open-ended methods are necessary because some dimensions of metacognition "are too complex and multifaceted to yield to simple measurement on a likert scale" (p. 50). Finally, because there is no unified definition of what comprises an effective online search, nor the cognitive and metacognitive knowledge and skills utilized in 'effective' searches, open-ended measures that elucidate the unique knowledge and strategies employed by individuals are well suited to future research in this area.

[6] In particular, methods employed in these studies included (but were not limited to): think-aloud protocols, browser histories or audit-trails of web navigation, videos of searches, interviews, assessments of pre- and post- knowledge, and collection of demographic information.

Research Design

The qualitative research design for this study aimed to balance two goals: to obtain rich data on science teacher's online strategies and associated cognition and metacognition, while approximating, as closely as possible, teacher's typical experience of web searching. Multiple methods of data collection were utilized to provide a more credible description of participants' cognition and metacognition than a single means could provide (Garner & Alexander, 1989; Veenman et al., 2006) and because the collection and integration of data from a variety of sources is recommended for qualitative research (Yin, 2011). A more detailed description of participant recruitment and the phases of data collection and analysis are outlined in the following sections.

Participants.

Participant Recruitment. This study aimed to recruit teachers who had one or more years experience teaching science in the K-12 education system, either in Alberta or elsewhere. Participants were recruited using one of two methods: 1) teachers known to the researcher were invited to participate in the study through phone or email contact; 2) intermediaries (such as past colleagues of the researcher) were sent an introductory email that was forwarded on to science teachers known by the intermediary. Any individuals interested in participating in the research then contacted the researcher directly. Teachers that expressed interest were then provided with a letter of introduction and a consent form through mail, fax, or email.

Participant Profiles. In general, the teachers recruited for this study were experienced teachers (all had a minimum of five years teaching experience) who taught science at the secondary level. The average experience level of teachers was 15.6 years (see Table 1). Of the eleven participants, five were female and six were male.

Table 1

Participants' Years of Teaching Experience and Past Science Courses Taught

Teacher	Years Teaching Experience	Past Science Courses Taught
A	8	Science 10-4, 10, 20, 14, 20-4, 30; Biology 20, 30; Chemistry 20, 30; Physics 20, 30
B	40	Physics 10, 20, 30 (AP, IB, & Regular); Chem 20, Science 10 (AP & Regular), Science 4-9
C	10	Science 10, 14; Bio 20; Physics 20, 30
D	5	Science 7, 8, 9; Bio 20,30 (AP & Regular); Physics 20; Chem 20 (AP & Regular); Science 10 (AP& Regular)
E	8	UK: Science Year 7-11, Level A Physics 12; Alberta: Science 10, Physics 20, (AP & Regular); Chem 20, 30 (AP & Regular)
F	30	Physics 10, 20, 30; Chemistry 10, 20, 30; Biology 10, 20, 30; Science 10, 20, 30; Environmental Science AP; Science 11, 15, 25
G	10	UK: Science Year 7, 8, 9 (General), Year 10, 11; Bio, A level Bio (12 &13). Alberta: Grade 9
H	28	Biology 20, 30, 35; Science 10, 14, 24; Chem 20, 30, (IB, AP); K&E Science (20-4)
I	11	Grade 7-9 Science; Bio 20, 30; Chem 20, 30; Science 10, 20, 30; Physics 20, 30; Science 14, 24
J	10	Science 5, 6, 7, 8, 9, 10 Honours. Bio 30; Chem 30
K	12	Science 10, 14, 20, 24; Bio 20, 30, 35 (AP & Regular)

Data collection. Data collection for this study involved two phases for each participating teacher. Phase I involved a 30-min online search on a topic of

the teachers' choice, relating to their science teaching. Phase II was a 50 to 75 minute semi-structured interview, conducted within one week of the 30-min search. Both Phase I and II will be described in more detail in the following sections. In addition, a more detailed description of the particular methods of data collection utilized in each phase will be provided within these sections.

Phase I: Teachers' 30-min searches. Phase I of data collection involved two primary methods of data collection: think-aloud protocol and observation. After a teacher provided informed consent to participate in the study, they selected a time and date of their convenience to conduct a 30-min online search on a science teaching topic of their choice. Each 30-min search session took place in a quiet, private space at the University of Alberta. Teachers could search for information or resources related to their current science teaching assignment, or on a science topic that was of interest to them (See Appendix A for a summary of teachers' search goals). Teachers were allowed to select their own search topic such that data would be more representative of teachers' typical searches than if the topic was generated by the researcher. While it would have been ideal for teachers to use their own computers, the cost to purchase and time to undertake installation of necessary software was prohibitive; hence teachers used a computer provided by the researcher to conduct their web searches.[7]

During the web search, a think-aloud protocol (Anderson, Nashon, & Thomas, 2009; Connell, 1995; Veenman et al., 2006) was used in which each participating teacher was asked to say out loud everything they thought or that

[7] With the exception of Teacher D, who used his own computer. Teacher D had screen-capture software already installed on his computer. The screen-capture file was saved on Teacher D's computer and a copy was then transferred to the researcher's computer.

occurred to them while they were conducting their search. Think-aloud protocol is typically utilized for individual (rather than group) assessments of cognition or metacognition and provides insight in to an individual's thinking while they are performing a task, which few other methods accomplish (Anderson et al., 2009**;** Veenman et al., 2006). As with other research methods, think-aloud methods also have a number of limitations. First, it is important to recognize that the act of verbalization during a task can potentially alter an individuals' thinking, which has implications for research (Hacker & Dunlosky, 2003). In addition, this method may not provide a complete picture of an individuals' thoughts because not all thoughts are verbalized (Connell, 1995). To this end, Connell (1995) states:

> In fact, there is evidence that the greater the experience with a task, the more automatic the process of performing the task. This means that intermediate steps in the process are carried out without conscious thought and therefore, without verbalization. (p. 507)

While these limitations are significant, the potential of think-aloud methods to provide insight on an individuals' thinking during task performance is unparalleled by other means currently available, thus the think-aloud method is widely used in metacognitive research (see Connell, 1995; Cromley & Azevedo, 2009; Hacker & Dunlosky, 2003; Hill & Hannafin, 1996; Hofer, 2004) and has also been employed in several studies targeting search strategies without a specific focus on metacognition (see Barker, 2009; Porter, 2011).

In addition to the use of think-aloud protocol, observations of teachers' searches was another important aspect of data collection for this study.

Observations are frequently used in conjunction with other methods of data collection in studies of cognition and metacognition (see Anderson et al., 2009; Barker, 2009; Cromley & Azevedo, 2009; Hill & Hannafin, 1996; Porter, 2011; Recker et al., 2004). Related to research on metacognition, observations in generally take place in person or through the analysis of video; it is important to note that both means of observation have the potential to cause some discomfort for participants, or influence participants' behavior (see Anderson et al, 2009; Cromley & Azevedo, 2009). In order to reduce the intrusion to participating teachers while conducting their searches, the researcher in this study situated herself at a distance where direct observation of the computer screen could not be undertaken while the teacher conducted their search. The researcher was present in the room during the search to remind teachers to think-aloud, or to answer questions, if required, but otherwise allowed teachers to conduct their search undisturbed. Thus, screen-capture software (Camtasia Studio®) was installed on the researcher's computer: This software recorded online movements and provided concurrent audio and video records of each teacher's think-aloud statements and facial expression (see Footnote 7). Observations of teachers' behavior were carried out by reviewing the screen-capture video after the teacher completed their 30-min search.

In addition to think-aloud data and observations, there were several other (secondary) sources of data generated from the 30-min search. First, teachers provided a brief written summary of their search goals prior to conducting their search (see Appendix A). In addition, the computer's browser history for the 30-

min search was saved for the purposes of reference. Finally, teachers were permitted to take notes (either in a word document or on a piece of paper) during their search or keep a list of website links, if they chose to do so. At the end of the 30-min search, teachers were permitted to keep a copy of their notes or links. If teachers took notes by hand, the researcher photocopied these notes for the participant and kept the original for analysis. If teachers took notes in a word document, the document was saved for use in analysis and a copy was emailed to the teacher or printed, according to their preference.

Phase II: Post-search interview. Within one week of their initial meeting with the researcher for the web searching session (Phase I), each teacher participated in a semi-structured interview. This interview was typically between 50 and 75 minutes in duration and was conducted in a quiet location convenient for the participating teacher. The interview was audio-recorded and transcribed; teachers were provided with a digital transcript of their interview, if they wished to have one. Clips from the audio and video file of the teacher and screen-capture video from the 30-min search were utilized in the interview to prompt the teachers to explain their thinking during the web search, which is called stimulated recall (Anderson et al., 2009). In general, stimulated recall events, in which participants are reminded of a past event during an interview, are frequently used in research on metacognition (Anderson et al., 2009; Veenman et al., 2006) and have also been employed in studies of online searching behaviors or strategies more generally (Julien & Barker, 2009; Perrault, 2007; Porter, 2011; Recker et al., 2004; Williams & Coles, 2007b). These methods have the potential to provide

rich data on an individual's thinking and provide an opportunity for researchers to clarify previous statements made by participants as well as discuss the accuracy of researcher's categorization of data (see Connell, 1995).

Where stimulated recall is employed in research, Anderson et al. (2009) argue that it is beneficial for participants to preview audio or video recordings prior to interviews, as this provides participants more time to reflect on their experience and "repeated dialectic reflection aids in deeper self insights about one's own learning and metacognition" (p. 188). While teachers in this study did not have the opportunity to view video recordings prior to their interview, they were provided with transcripts of their web searches prior to their interview, to aid in their reflection. It should also be noted that the potential of methods to deepen an individual's insights has implications for research purposes: interviews and recall events can serve as metacognitive interventions, in themselves, and can influence both the research participants and the variables being investigated (Anderson et al., 2009; Thomas, 2013; Welzel & Roth, 1998). In addition, interviews and stimulated recall events can be somewhat intrusive for participants and can require a significant time investment on the part of the researcher and participant (Anderson et al., 2009). However, despite these potential pitfalls, "most interpretive studies of metacognition in the field of science education employ some form of interview methods in order to explore participants' metacognitive attributes, states, or changes in state" (Anderson et al., 2009, p. 190). Indeed, the post-search interview played an important role in data collection in this study: it provided an opportunity for clarification of web-search data and of

initial coding, as highlighted above and also extended teachers' opportunity to describe their typical experience as they search online. Examples of questions used in the post-search interview are provided in Appendix B.

Data Analysis. Data analysis for this study was conducted in two phases. Phase I involved the initial analysis of each teacher's 30-min search data, for the purpose of developing initial codes and to generate questions for the post-search interview. Phase II involved analysis of all teachers' 30-min search data as well as post-search interview transcripts to identify overall themes related to teachers' use of the internet to support their teaching, as well as their thinking and metacognition related to web searching and the evaluation of resources found online. Both Phase I and II will be described in more detail in the following sections.

Phase I: Initial analysis of teachers' 30-min searches. Immediately following each 30-min web searching session, the researcher watched the screen capture video and took notes relating to the teacher's behaviors and thinking. The researcher then listened to the audio file from the 30-min search and transcribed the search verbatim. The video and transcript were each reviewed between one and three more times by the researcher prior to interviewing the teacher; this served to identify emerging codes and to generate both general and individualized interview questions for use in the post-search interview. Samples of general and specific research questions utilized in the post search interview are provided in Appendix B. Generation of codes was guided by teachers' actions and statements from the web search video as well as the research questions and the metacognitive

framework outlined in Chapters 1 and 2. Some predetermined codes were utilized for this study, in particular those related to teachers' metacognition (see Appendix C); all other codes emerged from the data and related to teachers' actions and thinking (see Appendix D). Creswell (2009) highlights that researchers must consider whether it is appropriate to use predetermined codes, to develop codes based on emerging information, or to use a combination of the two approaches when analyzing data. For this study, using a combination of predetermined and emerging codes was suitable, as the research was guided by a theoretical framework but was exploratory in nature (Creswell, 2009).

Phase II: Analysis of post-search interview and identification of themes. After post-search interviews were conducted, audio recordings were transcribed and input into NVivo, along with teachers' web search videos and transcripts from the web searches. The initial coding scheme was further developed and revised based upon in-depth analysis of teacher's web search videos, web search transcripts, and interview transcripts, as well as consideration of the metacognitive framework outlined in Chapter 2. Analysis of web search and interview data took place on an individual level first and upon completion of all interviews, at a group level. Teachers' actions during the web search were coded from the video data of teachers' 30-min search and summary statistics[8] were generated; teachers' cognition and metacognition were coded from transcripts of teachers' audio during the web search and post-search interview (See Appendix C for a summary of the coding scheme related to teachers' metacognition and

[8] Counts of codes were generated; percent of total search time spent on each task was also calculated (see Table 3, Chapter 4).

Appendix D for a summary of the coding scheme related to teachers' thinking and actions). Attention was paid to identifying themes that emerged from the data, particularly in relation to search strategies and resource evaluation. In addition, all transcripts were also reviewed once again by the researcher with a specific focus of drawing out statements that related specifically to teachers' metacognition.

Validity and Reliability

Validity in a qualitative study "means that the researcher checks for the accuracy of the findings by employing certain procedures" (Creswell, 2009, p. 190). In particular, Creswell suggests using multiple data sources, employing member-checking, and using peer debriefing to increase the accuracy of the work, among other suggestions. Being attentive to concerns of validity, this study collected data from multiple sources (videos of web searches, think-out-loud data, records of teachers' search terms and sites visited, as well as interviews) and from several participants in order to build a coherent and well-supported justification for the themes presented (Creswell, 2009). Member checking was employed through the use of a follow up-interview; participants were given the opportunity to comment on the initial codes and interpretations made by the researcher, which also helps to enhance the validity of the study (Connell, 1995; Creswell, 2009). This study also utilized peer debriefing, that is, the researcher's supervisors reviewed and asked questions about the study because "involving an interpretation beyond the researcher... adds validity to an account" (Creswell, 2009, p.192).

Reliability in qualitative research relates to consistency in the research approach (Creswell, 2009). Several suggestions made by Gibbs (2007) related to

enhancing the reliability of qualitative work were incorporated in the design of this study, including: re-checking transcripts for transcription errors and ensuring that code definitions do not drift by using constant comparison of data and codes and by writing out code definitions (see Appendices C and D). In addition, Creswell (2009) highlights that qualitative researchers should thoroughly document the procedures utilized in their research, which was done for this study. Finally, while cross-checking all codes with another researcher is suggested (Gibbs, 2007), this was not an option for this study, as this work was conducted by a single researcher. However, a sample set of data was cross-checked with an independent researcher working in the areas of metacognition and science education.

Ethics

Prior to conducting this research, the research proposal for this study was reviewed and approved by the Research Ethics Board at the University of Alberta to ensure adherence to ethical guidelines. The study procedures outlined in the proposal were frequently reviewed and strictly followed throughout data collection, analysis, and reporting of results.

Delimitations

While this study could contribute to a more general investigation of teachers' search strategies and related cognition and metacognition, the focus for this research was narrowed to science teachers, due to the context-dependent nature of some cognitive and metacognitive processes (Anderson et al., 2009). In addition, because this research aimed to gain insight in to science teachers'

experience of engaging with science content related to their teaching practice, this study has been delimited to teachers who have had at least one year of teaching experience within the K-12 education system (in Alberta or elsewhere) as this experience provides relevant context for teachers to draw upon. Data collection for the searching component of the study was restricted to a single 30-min session and the post-search interview was limited to approximately one hour for each participating teacher; as it is the researcher's belief that this would permit the collection of rich data on teachers' thinking during their search without making participation in the study onerous for teachers. Finally, only eleven participants were recruited to ensure that the time required for data collection and analysis would be reasonable for a single researcher.

Chapter 4

Results and Discussion

The results and discussion of data collected in this study will be presented in five sections. The first section, *Use of the Web: Background Information and Analytics,* summarizes teachers' responses to interview questions pertaining to their general searching behaviour and describes teachers' actions during their 30-min search, as determined from screen capture data. Topics covered in this section include teachers' reports of their typical web use, expressions of confidence using the web, and their interest in accessing professional development in this area. In addition, this section will provide a brief description of the types of resources teachers preferred to access and the prominent actions undertaken by teachers during their 30-min search. This data is intended to provide context for discussion in subsequent sections, which describe teachers' cognition and metacognition related to their online search.

The second section, *Teachers' Thinking Related to Searching Online* aims to answer research question one and will provide discussion of teachers': (a) generation and refinement of search terms, (b) decision making in a search engine results page (SERP), and (c) referencing and note taking. Data for this section was derived from teachers' think-aloud statements and post-search interviews. The third section, *Teacher's Thinking Related to the Evaluation of Resources Found Online* aims to answer the second research question. This section also draws on teachers' think-aloud statements from the 30-min web search as well as teachers' explanations of their thinking elicited during the follow-up interview. The fourth

section, *Teachers' Metacognition Related to Web Searching* aims to address research question three by summarizing the overall findings of this study relating to teachers' metacognition. It will draw on data from teachers' think-aloud transcripts and the post-search interview. Finally, it should be noted that relevant aspects of the information literacy framework described in Chapter 1 will be discussed throughout this chapter such that the actions and thinking of teachers in this study can be compared to those outlined in information literacy frameworks.

Use of the Web: Background Information and Analytics

This section seeks to briefly highlight the ways in which teachers in this study typically utilized the web to support their teaching practice and provide a description of teachers' perceptions of their typical internet use. In addition, it will summarize the types of resources teachers preferred and identify some of the general characteristics of teachers' 30-min web searches.

Teachers' typical use of the web. Teachers indicated the number of hours they spent searching related to their teaching varied from zero hours a week to five or more hours a week, depending on the familiarity of the teaching assignment or a perceived need by the teacher. All eleven teachers indicated they used the internet most frequently to learn about science or prepare for their teaching, in comparison to utilizing other sources (such as television, radio, news-paper articles, magazines, or books). Two major themes emerged from teachers' responses as to why they used the internet more frequently than other sources of science information; specifically, the teachers saw the internet as being convenient and accessible to use (nine teachers) and providing a gateway to a

broad range of information and resources (seven teachers). These findings are similar to those reported by Williams and Coles (2007b), in the UK, where teachers "...often cited the Internet as the first or second source they would turn to when searching for external information... benefits were seen to be accessibility and speed, the availability of specialist information and currency of information on the web" (p. 200).

Confidence related to web use. Of the eleven teachers in this study, ten stated that they felt confident in their ability to use the internet to find science information or teaching resources. This expression of confidence by teachers in their ability to find general information has been noted in other research as well (see Perrault, 2007; Williams & Coles, 2007b). In addition, all eleven teachers indicated that they are typically successful in their searches; that is, they responded that they *usually* or *always* find what they are looking for online. Similarly, in a study by Perrault (2007), 80% of biology teachers surveyed about their internet use indicated they *often* or *always* found what they were looking for when using search engines. It should also be noted, however, that other research has shown that teachers may over estimate their web searching abilities (Wang, 2007).

Teachers in this study indicated that if they were unsuccessful in locating science information or a particular resource related to their teaching, they felt it could be because: a) they ran out of time or lacked time (five teachers), b) their particular search strategy was not effective (three teachers), or c) the resource or information they were looking for is not available online (three teachers). Similar

results were reported in Williams and Coles (2007b) study on teachers' approaches to finding and utilizing research evidence; lack of time was cited as the most significant barrier to teachers' use of research evidence to inform their professional practice. Perrault (2007) also found that teachers reported lack of time as the primary reason for non-use of online databases, digital libraries, and web sites.

Training and professional development related to online searching. Of the eleven participating teachers in this study, only two indicated that they had taken some training related to online searching, though this training was not specific to web searching in science. When asked if they would be interested in attending professional development (PD) related to improving their online searching skills related to science, two teachers articulated that they would be interested, three teachers stated that they may be interested (depending on what exactly was offered), and the remaining seven teachers indicated they would not be interested. These findings are in contrast to those reported by Perrault (2007), who surveyed 70 biology teachers about their information seeking and found that "regardless of the experience level as a teacher or Internet user, the majority of study participants expressed an interest in refining their skills" (Discussion section, para. 5). While further evidence is needed to validate this claim, teachers' statements in this study seemed to indicate that teachers' level of confidence in their web searching abilities and overall comfort with their subject areas were factors that influenced their interest in pursuing PD related to web searching.

Preferred resources. Teachers indicated during their post-search interview that they typically used the web to: find subject information (for their own learning or information, or for the purpose of improving their teaching notes or resources), generate ideas for resource development (labs or activities), or to locate resources that could be used as is or adapted (such as images, videos, assessment items, or labs). That teachers' used the web for a variety of informational and instructional resources is also supported by other research (Perrault, 2007; Recker et al., 2004). In addition, most teachers in this study did not look for complete lesson plans; rather they preferred resources that could be inserted into their instruction where and when they saw fit, which was also found by Recker et al. Finally, teachers preferred resources that were provided in formats that were easy to download, modify, and adapt to their intended use (such as inserting a video or image into PowerPoint or Smart software), which has also been noted in other research (Recker et al., 2004).

Teachers' search goals and web search analytics. This section will provide a brief description of teachers' search goals and highlight the general characteristics of teachers' 30-min web searches. These descriptions are intended to provide the reader with an understanding of the context in which teachers framed and conducted their searches. Further, these contextual descriptions should aid the reader in drawing meaningful conclusions from subsequent sections that discuss teachers' cognition and metacognition. Data for this section was generated through analysis of teachers search goals (which they described, in writing, prior

to beginning their 30-min search) and through the analysis of teachers' screen capture video.

Search goals. While a detailed analysis of teachers' search goals is not a major focus of this study, all teachers' search goals were coded as being related to content or instruction / pedagogy (See Appendix A). Teachers' goals could be coded at more than one category (for example, a teacher could be interested in finding projects and lab ideas, such as Teacher A). The most common goals for teachers related to: finding content information (five teachers), project or activity ideas (four teachers) or labs (four teachers). Other goals described by teachers (such as finding animations or supplemental material for students) are identified in Appendix A.

Web-search analytics. As is evident in Table 2, teachers typically spent the largest proportion (mean 40.8%) of their total search time within a website, typically either reading text or navigating the site. Four teachers (A, G, I and K) visited websites that contained collections of resources or external links, so these teachers also spent some time evaluating whether or not they would click on links to move to other websites/pages or resources. All teachers utilized Google as their search engine (see Appendix E) and all teachers spent time entering search terms in a search engine page (mean 6.2% of total search time) and subsequently evaluating results on a search engine results page (SERP) (mean 13.1% of total search time). In addition, all teachers undertook note taking, either hand written or electronically, during their search. Finally, watching videos was an activity

undertaken by seven of the eleven teachers participating in the study. Other actions that teachers undertook are outlined in Table 2.

Summary of background information and analytics. Overall, teachers in this study indicated they were more likely to utilize the internet for science information or to support their teaching than other means (such as books, television, newspapers, radio, etc). Teachers viewed the web as being convenient and accessible to use and felt it provided a gateway to a broad range of information and resources. Teachers felt confident in their ability to use the internet related to their teaching and most teachers were not interested in attending professional development related to web use. Teachers indicated that they tended to use the web to search for content information, to generate ideas, or to locate resources that could be utilized for their teaching and generally preferred smaller resources in formats that permitted easy adaptation to suit their teaching context over full lesson plans, which has been found elsewhere (Recker et al., 2004). Teachers had varied search goals related to their 30-min search, but goals most cited by teachers related to finding content information, project ideas, or lab exercises. Finally, while teachers undertook a number of actions during their 30-min web searches, the largest proportion of teachers' time was spent either reading text or navigating within websites.

Table 2
Teachers' Percent of Total Search Time Spent Per Activity

	Teacher											
Action	A	B	C	D	E	F	G	H	I	J	K	Mean
Closing Windows / Exiting Site	1.0	0.3	0.3	1.5	0.8	0.5	2.1	1.6	1.0	1.7	0.7	1.0
Examining Images	3.0	8.9	0.0	3.8	0.0	1.7	9.0	0.0	4.0	0.0	2.4	3.0
In Website	45.7	46.3	17.2	23.1	7.9	70.0	30.9	36.7	44.7	58.7	67.6	40.8
i) Website Exploration or Reading	32.3	46.3	17.2	23.1	7.9	70.0	26.4	36.7	28.8	58.7	53.2	36.4
ii) Evaluating Results in a Webpage	13.4	0.0	0.0	0.0	0.0	0.0	4.5	0.0	0.4	0.0	14.4	3.0
iii) Taking Online Quiz	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	15.5	0.0	0.0	1.4
Logging In	1.0	0.0	0.0	3.3	0.0	0.0	1.8	0.0	0.0	0.0	0.0	0.6
Other	3.4	5.8	5.0	0.2	17.9	6.7	0.3	3.1	0.5	2.4	2.0	4.3
Program of Study	6.2	0.0	0.0	2.3	0.0	0.0	0.0	18.4	0.0	0.0	11.2	3.5
Search Engine Page: Entering Terms	4.6	11.3	6.6	3.9	2.8	3.3	6.5	4.4	7.9	11.4	4.9	6.2
Search Within Document or Site	2.2	0.0	0.0	0.8	0.0	0.0	0.7	0.0	0.0	0.6	0.2	0.4
Search Engine Results Page	17.8	22.7	8.4	9.8	9.4	14.2	13.2	10.0	17.8	13.8	7.4	13.1
Typing in URL or Direct to Site	0.0	0.0	2.1	0.4	0.0	0.0	0.9	0.4	0.0	0.0	0.2	0.4
Watching Video	4.4	0.0	54.0	19.0	39.9	0.0	17.0	0.0	18.2	0.0	1.4	14.0
Writing Notes	8.7	4.8	6.5	5.4	17.2	3.6	8.8	25.4	5.9	9.3	2.1	8.9
i) Writing Notes on Computer	0.0	4.8	0.0	0.0	12.5	0.0	8.8	25.4	0.0	9.3	0.0	5.5
ii)Writing Notes on Paper	8.7	0.0	6.5	5.4	4.6	3.6	0.0	0.0	5.9	0.0	2.1	3.4
Consulting Own Resources	0.0	0.0	0.0	13.6	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.2
Organization	0.0	0.0	0.0	4.0	0.0	0.0	0.5	0.0	0.0	0.0	0.0	0.4
Saving Resource or Document	2.0	0.0	0.0	8.9	4.0	0.0	8.3	0.0	0.0	1.9	0.0	2.3

Teachers' Thinking Related to Searching Online

This section aims to answer the first research question: *what are the thought processes science teachers' use when searching for science information or resources online?* It will highlight themes that emerged from the coding of teachers' verbal descriptions of their actions during the web search (the think-out loud audio recordings) and coding of teachers' responses during their post-search interview. This section will be further broken in to three sub-sections related to teachers' thinking, which address: (a) generation and refinement of search terms, (b) decision making in a search engine results page (SERP), and (c) referencing and note taking.

Generation and refinement of search terms. While a detailed analysis of teachers' search terms is not a major focus of this study, all teachers' search terms from the 30-min search were coded as being related to: a subject (ex "photosynthesis"), teaching (ex "labs"), or to searching for a specific site (ex "YouTube"). A complete summary of teachers' search terms are provided in Appendix A. Through the analysis of teachers' search terms in relation to their think out-loud data and post search interview, several themes emerged that provided insight on how teachers went about generating their search terms or phrases. Specifically, teachers: drew on their science knowledge and past teaching experience, utilized the Program of Studies, used Wikipedia, and employed features of the search engine (autocomplete). Each of these areas will be discussed, briefly, followed by a description of teachers' refinement of search terms.

Drawing on previous knowledge. While it is difficult to capture instances where teachers' drew upon their previous knowledge to generate search terms (as this process is internal to teachers and may not have been explicitly articulated during the think-out-loud search), there was evidence that ten of eleven teachers drew upon their science knowledge and/ or previous teaching experience in the generation of search terms. Seven teachers (B, C, E, F, G, I, and J) initiated their search with terms they self-generated (as opposed to terms they found in documents such as the Program of Studies, as described in the following section); typically these terms were consistent with the written description of the search goals teachers provided prior to beginning their search. For example, prior to beginning his web search, Teacher B indicated his search goal was to "find more information relating to definition of mass and force." Teacher B's first search phrase was "mass and force" (See Appendix A), which highlights that Teacher B was drawing on his prior knowledge (and perceived information need) to generate his initial search terms.

Further evidence that teachers' drew on previous knowledge in their generation of search terms throughout their search is provided by teachers' statements from the web search and post-search interview. For example, Teacher C was searching for resources related to Dalton's atomic theory for the first ten minutes of his web search, then decided he was going to move on to a different scientist. He stated: "I know lots about this guy, more than I do Dalton... [enters search term: Thomson] I do talk about how his discovery of the charge to mass ratio of the cathode ray particles resulted in the discovery of the electron, but let's

see if I can get more." What is evident from Teacher C's statements (and clarified through analysis of the web search video) is that Teacher C was not utilizing key words from a website or particular resource he had recently looked at, rather he was drawing on his own knowledge of scientists' work related to the development of atomic models in order to generate search terms. Similar instances where teachers' statements coupled with analysis of the web search video indicated that teachers' drew upon their own knowledge to generate search terms occurred for eight teachers (A, B, C, D, E, F, J, and K). Thus, when combined with the findings related to teachers' initiation of their searches (described in the previous paragraph), a total of ten of the eleven teachers in this study drew upon their previous knowledge for the generation of search terms.

The only teacher who did not provide explicit evidence of drawing on previous knowledge in the generation of search terms was Teacher H; however, Teacher H also indicated that the topic of her search (Science 24 Transportation Safety) was one that she was not very familiar with, hence her ability to draw on previous knowledge may have been limited. In addition, Teacher H indicated in the post-search interview that her approach to conducting her search may have been different if she was more familiar with the topic: "if had been familiar with something that I had seen before, then I would try to find that... instead of just going out there and searching for something [and] I don't know what I'm looking for" (Teacher H). This finding implies that teachers may utilize different search strategies depending on their content knowledge and experience with a topic, which may have implications for beginning teachers.

Drawing on the Program of Studies. Four teachers (A, D, H, and K) consulted the Program of Studies (POS) directly during their search and four additional teachers (C, F, I and J) indicated in the post-search interview that they kept the POS in mind while conducting their searches. Teachers that consulted the Program of Studies directly used keywords or sometimes entire phrases from POS as their search terms. For example, Teacher H used search terms (See Appendix A) that she pulled from the Science 24 Program of Studies, such as "highway safety statistics for Alberta" and "causes of death or injury in Canada adults and teenagers" because the Science 24 Program of Studies stated that students must: "compare the death and injury rate in motor vehicle accidents to other causes of death and injury among adults and teenagers" (Alberta Education, 2003). Teacher K also indicated in her post search interview that using key words (and sometimes exact phrases) from the POS as search terms is something she would do "all the time" (Teacher K).

Teachers that did not consult the POS directly during their search indicated that this was due to their familiarity with the document. For example, Teacher F stated that he doesn't always refer to the POS directly because:

> For physics ... I've worked so much with it over the last couple years... almost to the point where I know each of the subject headings... I know which number they are. For bio / chem, [areas he had less experience in] I tend to look at the program of studies if I'm looking for something. That would actually be my starting point. (Teacher F)

Overall, teachers indicated that when they are relatively familiar with their subject area and the POS, their use of the POS to help guide their search and generate search terms may be somewhat less frequent than it would be if they were a new teacher, or if they were preparing to teach a particular course for the first time.

Other strategies utilized to generate search terms: Wikipedia and autocomplete. Two other strategies were used by teachers to generate search terms: the use of Wikipedia and autocomplete. Three of the eleven teachers indicated they use Wikipedia to help them generate search terms (Teachers G, H and I). These teachers indicated that Wikipedia aided them in finding synonyms or words closely associated with their topic of interest, thus they could use these words or phrases to conduct searches. The use of Wikipedia for idea generation during web searches has been documented in other research as well (see Porter, 2011).

Three teachers (E, F, and I) utilized the autocomplete feature in Google. This means that teachers would begin typing search terms (such as "cellular respiration") and then click on a search phrase that was automatically completed by Google (such as "cellular respiration for kids"). While this was not a strategy commonly used by the eleven teachers in the study, the teachers who employed the autocomplete feature highlighted that it helped them generate search terms or consider other areas they could investigate during their searches.

Refinement of search terms. Based on teachers' think out loud statements and explanations provided during the post-search interview, teachers provided two primary reasons for refining their search terms. Either they were (a)

dissatisfied with their results and believed that modifying their search terms would provide them with new results relating to the same topic, or (b) moving on to a new search (new topic) because they were either satisfied with what they had found, became interested in a new area of investigation, or felt they had exhausted their options. All teachers exhibited both of these types of search refinement at least once during their 30-min search (see Appendix A for teachers' search terms).

Typically, when teachers refined their search terms because they were dissatisfied with their results but wanted to continue searching relating to their current topic, they made their search terms more specific, which was observed in the searches of eight teachers (A, C, D, E, G, H, I and J). For example, at approximately 15 minutes in her search, Teacher A expressed dissatisfaction with the search results that were returned from the search terms 'photosynthesis lab'. She stated: "...and then I'll probably look at this and say... ok, you need to be way more specific. And I'm going to say 'photosynthesis lab and biochemistry' because I'm wanting the biochemistry piece" (Teacher A). Teacher A then modified her search terms to 'photosynthesis lab and biochemistry' (see Appendix A). While in some instances, teachers narrowed their searches by adding terms that were more specific to their topic (such as Teacher A, in the previous example), there were also instances where teachers narrowed their searches in relation to their pedagogical needs, by indicating the type of resource they were looking for (labs, quizzes, activities) or the age group (high school, kids). For example, Teacher I was searching generally related to 'cellular respiration' then stated "... so I could probably narrow it down. If I went to cellular respiration for kids... I wonder if

kids would simplify it too much. Though some of the students do need it pretty simple" (Teacher I). Teacher I then modified her search to 'cellular respiration for kids' (see Appendix A).

As mentioned previously, when teachers moved on to a new topic (new search), they generally did so because they were either satisfied with what they had found, became interested in a new area of investigation, or felt they had exhausted their options. For example, Teacher J was searching for information on historical types of canoes and the building of canoe models that he could incorporate in to the Grade 7 unit Plants for Food and Fibre, when he came across the word 'paddle' on a website (related to canoes). He then expressed interest in the idea of having students making their own paddle and subsequently changed his search terms to 'Canada paddle blanks' to reflect the new area of interest for his search (see Appendix A). Other teachers experienced dissatisfaction with their search results, which motivated a change in topic. For example, from time 16 min 28 s to time 20 min in her web search, Teacher K was looking for 'understanding the ear activities', but at time 20 min felt she had exhausted her options and decided to shift to searching for 'endocrine system activities' (See Appendix A). Similar instances where teachers explicitly expressed dissatisfaction with search results and moved on to new search topics also occurred for Teachers A, D and J.

Factors teachers considered within a search engine results page (SERP). Teachers considered several factors when looking through results on a SERP (refer to Appendix F for a sample SERP with labels). In particular, teachers looked at the title of a website and the site description provided on the SERP, as

well as the URL to make judgements about whether or not they would navigate to a particular site. In addition, teachers also made judgments about sites based on past experience (positive or negative) with the site. Each of these areas will be addressed in greater detail in the following sections.

Website title and description. All eleven teachers noted the site title or description provided on the SERP when reading through search results to determine what sites to navigate to. However, it should be noted that while there was evidence from the 30-min search that teachers' attended to the site title or description (they read them out loud or scrolled their mouse over them), teachers rarely articulated their reasoning behind selecting a particular website on the SERP while they were searching. During the post-search interview, some teachers indicated that they were comparing website titles and descriptions to an internal search goal. For example, Teacher F was asked to explain why he selected a particular website (National Physical Laboratory, 2013) from a SERP during his search. He stated he was looking at the website URL (addressed in the following section) and also noticed the keyword 'measures' which appeared below the website title. At that time in his search, Teacher F indicated that "the measurements are the things I'm looking for"; hence he selected the resource, in part, because the key words presented on the SERP matched his search goals.

Website URL. While some teachers explicitly mentioned website URL's during their 30-min web search, teachers did not elaborate on their thinking related to how they made judgements about sites based on the URL. As a result, teachers were asked in the post-search interview if, while searching, they typically

notice or consider whether a site's URL contains .com, .org, .edu or some other domain name. Of the 11 teachers in this study, six teachers (F, G, H, I, J and K) indicated that they consider a website URL when making judgments of a site listed on the SERP. One teacher (Teacher A) stated that she may or may not consider a URL when selecting resources from the SERP or when evaluating a site.

Those teachers that considered the URL of a site indicated that it helped them make an assessment of the credibility or trustworthiness of a site, though teachers were clear that this was not their only means of assessing the credibility of a site (discussed in subsequent sections). These teachers felt that sites with .edu domain names or that indicated a government affiliation (.gc.ca, for example) were typically more credible than sites with .com domain names. These teachers were also skeptical of the credibility of .org sites. For example, Teacher H explained her thinking related to domain names during the post search interview: "I would be suspicious of .com. ... .edu less so, depending upon the edu. And .org ...very much I would have to look at what kind of .org it is. Some of them I trust and some of them I don't" (Teacher H).

In contrast to the views of Teacher H, four teachers (B, C, D, and E) indicated that they do not consider the URL of a website when making judgments about the website or when sifting through results on a SERP, because they felt that a domain name was not necessarily an indicator of the credibility or quality of a website. For example, Teacher D indicated in the post-search interview that he did not look at domain names:

> ...because even in a lot of those places [.edu sites], there's a lot of bad resources... there's a lot of .edu ones that are... not directly related to what my students have a use for. And then even some of the .com ones can be better than the .edu ones or .org ones. (Teacher D)

Similarly, Teacher A was attentive to domain names but highlighted that it was not always a criterion she used to make evaluations of a site. Overall, teachers in this study were divided as to whether they consider a website URL when making judgments of a site listed on a search engine results page.

Past experience with a site. Nine out of 11 teachers in the study indicated that they were familiar with a website (through either a positive or negative past experience) that came up at some point during their 30-min search. This is not a surprising finding, given that all teachers in the study had five or more years teaching experience, however, it should be noted that making judgments about resource quality based on past familiarity with a resource or site may be more common with this group of teachers than it would be, perhaps, with a less experienced group of teachers. Overall, a total of nine teachers in this study (A, B, C, D, F, G, I, J and K) indicated they selected a particular website or resource because of a positive experience in the past. Four teachers (A, B, F and I) indicated during their search that they would not use a particular site or resource because of a negative past experience, or because they were familiar with the resource already and were looking for something new. That teachers were attentive to their past experience with websites is consistent with other research investigating research strategies employed by adults (Porter, 2011).

Strategies related to referencing and note taking. This section will briefly describe different strategies teachers employed related to referencing and note taking during their 30-min search. Topics covered include teachers' use of multiple web-browser tabs, note taking, and saving resources by utilizing bookmarking, online storage, or subscription to you-tube channels. Each of these themes will be addressed, in turn.

Use of multiple browser tabs. All 11 teachers were observed to keep two or more browser tabs open during their web searches, however, at least three of these teachers (B, C, and H) indicated that they may not typically utilize this strategy in their online searches. In addition, it should be noted that four teachers (A, B, C and H) indicated they used browsers for the 30-min search that were atypical from what they normally used (See Appendix E), which may have influenced their use of browser tabs. The remaining eight teachers articulated that using multiple browser tabs was something they frequently did during their online searches. Several teachers explained in their post-search interview that this strategy made it easier to refer back to other resources they had located during their search, or to move back and forth from individual websites to the search engine results page. Teacher J utilized browser tabs in a unique way: he treated each tab he opened as a mental aside, as he closed tabs he moved back to his original search goal and topic and re-focused his search (Teacher J). Overall, the teachers who utilized browser tabs did so because they felt they helped them to mentally organize their searches and/or compare their search results.

Note taking. All eleven teachers were observed to take notes during their 30-min search, either by hand on a scrap piece of paper provided (teachers A, C, D, E, F, I, and K), or on the computer (using Microsoft Word, WordPad etc) (teachers B, E, G, H and J).[9] In general, most instances where teachers took notes involved them recording the location of a particular website or resource (by writing down the URL, website name, author, and/or search terms they used) such that they could return to the resource at a later date (10 teachers: A, B, C, D, E, F, G, H, I, K). Another common occurrence was for teachers to take their own notes (point form or in sentences) about ideas or concepts that arose during their 30-min search (6 Teachers: C, D, E, H, I, J). Additionally, three teachers (B, G, H) copy-pasted images or sections of text into a Microsoft Word or WordPad document to save and read through again at a later date.

While discussion of note-taking strategies was not a major area of focus for the post search interview, several teachers were prompted to elaborate on their use of note taking while searching online. Teacher E, in particular, was very articulate about how and why he utilized note taking. He indicated that taking point form notes was something he always did while watching videos "...because I want to chunk the information for the kids... so I have to chunk the information for myself. And again, that allows me to memorize it better and to understand it better and that's the way my mind works too... step form." Overall, note taking was a strategy that teachers used to organize and process information, which has been identified as an important skill in information literacy frameworks (Eisenberg et al., 2004).

[9] Teacher E took notes both by hand and on the computer.

Saving resources. Being able to effectively download, print, or otherwise save resources is a skill generally acknowledged as being required in information literacy models (ACRL, 2006; Eisenberg et al., 2004). Teachers in this study used several means (in addition to note taking) to keep track of resources or websites they found valuable. Three teachers (D, J, and K) bookmarked sites (or indicated they would do so), two teachers (D and G) used online storage, and one teacher (D) subscribed to a channel on YouTube. In general, teachers that utilized bookmarking indicated they only did so occasionally and that it was dependent on the computer they were using (at home versus at school). That teachers bookmark sites while conducting online searches for resources has also been found by Recker et al. (2004).

The teachers that utilized online storage had different reasons for doing so. Teacher D made use of a Google Site that he had previously set up and organized according to course and topic and saved resources he found during his search in folders he created on the site. In the post-search interview, Teacher D emphasized that he typically saved you-tube videos, lab manuals, and other resources to the shared site so that his colleagues and students would have access to the resources as well. In contrast to Teacher D, Teacher G used online storage (*Symbaloo*) for the purpose of her own reference, not necessarily to share the resources she found with other teachers or with students. In the post search interview, Teacher G explained the main advantages of her using Symbaloo: first, that it is accessible anywhere that she has internet access and second, that she can organize her

resources according to the way she thinks; she is able to create her own categories and color code resources.

Only Teacher D subscribed to a YouTube channel during his 30-min search. In his post-search interview, he indicated that he has subscriptions to numerous YouTube channels and found this beneficial because the subscriptions reminded him of resources that are already available and meant he got updates if new material was uploaded to any of the channels he subscribed to. While Teacher D indicated subscribing to a channel was a common and effective referencing strategy for him, no other teachers participating in the study identified this strategy as one they used related to their teaching.

Finally, it should also be noted that Teacher D was the only teacher to save resources to the computer during the 30-min search, as he opted to use his own computer. All other participating teachers used the researcher's computer for their 30-min search; while the researcher indicated to teachers that they could download files or bookmark sites during their 30-min search (and the researcher would provide the links / files to the teacher following the search), the majority of teachers opted not to do so. Teachers' decisions to download or save files was likely influenced by their using the researcher's computer, as will be discussed in Chapter 5, Limitations section.

Searching for resources: Section summary and comparison to information literacy standards. Overall, this section aimed to answer the research question: *what are the thought processes science teachers' use when searching for science information or resources online?* The major findings

described in this section related to teachers' generation and refinement of search terms, decision making within a search engine results page, and referencing and note taking. When comparing these findings to information literacy frameworks (described in Chapter 1), some conclusions can be made related to teachers' determination of their information needs, acquisition of information, and ethical and effective use of information, as will be described next.

Determining the information need. Also referred to as task definition or planning in some information literacy frameworks, this skill involves determining the purpose and need for information (ACRL, 2006; Eisenberg & Berkowitz, 2000). In this study, teachers defined their information need prior to conducting their web search (see Appendix A for teachers' search goals) and were not asked to explain how or why they came to identify their information need (as it was not a focus of this study). In addition, teachers determined their own information need and were not fulfilling the requirements of an assigned task; therefore it is difficult to make evaluations of teachers' skills related to determination of information needs. However, there was evidence that teachers reflected on their information needs throughout their searches (i.e. teachers verbally identified their search goals throughout the search) and the types of information they would need (such as factual information, images, or statistical data) which relates to effective determination of information needs in information literacy frameworks (ACRL, 2006; Eisenberg & Berkowitz, 2000).

Acquiring information. As highlighted in Chapter 1, acquiring information involves the determination and selection of different sources of

information, the use of effective search strategies, and the ability to refine search strategies, among other skills (ACRL, 2006; Eisenberg & Berkowitz, 2000).

Related to the determination of sources, teachers in this study were limited to using web-based resources (as the focus of the study was internet use); however, teachers could have employed multiple search engines, as well as utilized online library systems, resource collections, or other means of gathering information online (such as contacting individuals through email). While several teachers (A, B, D, F, J) indicated in their post search interview that they sometimes use these means to gather information online, teachers in this study utilized Google searches almost exclusively. In addition, no teachers in this study searched for scholarly education literature, which has been found in other studies of teachers' information literacy (Williams & Coles, 2007b). Related to the selection of sources, teachers demonstrated that they considered a number of criteria when selecting particular websites on a search engine results page, including the website title and description, the URL, and their past experience with the site. Overall, teachers' in this study did not demonstrate that they had considered all possible sources of locating information online, however, teachers were able to effectively select sources that they felt would meet their information needs.

Related to search strategies, teachers in this study drew upon their prior knowledge or teaching experience as well as other sources (Program of Studies, Wikipedia, autocomplete) to help them to generate effective search terms. Teachers demonstrated the ability to use keywords and synonyms and refine their

search terms to narrow their topic, which is consistent with literature related to effective information retrieval (ACRL, 2006; Alberta Learning, 2004). In particular, teachers in this study refined search terms when they experienced dissatisfaction with their search results, became interested in a new topic, or when they felt they had achieved their search goals and were prepared to move on to a new topic. In addition, teachers demonstrated several of the skills outlined by Eisenberg and Berkowitz (2000) related to locating information within sources, including using a table of contents, skimming material, and employing the search function within a document or page of text. Teachers in this study also used multiple web browser tabs to cross-reference resources and to organize their searches.

Finally, it should be noted that teachers did not employ some skills related to the effective access of information. For example, teachers did not demonstrate extensive use (or awareness) of Boolean operators, nor did they have the opportunity to demonstrate whether or not they would use search strategies tailored to particular information retrieval systems because they used Google exclusively. Overall, comparison of the results of this research to information literacy frameworks highlights that teachers in this study had strengths and areas of improvement related to their ability to determine their information needs and effectively acquire information.

Ethically and effectively using information. Another key component of information literacy frameworks reviewed for this paper is the effective and ethical use of information. This involves the synthesis of information from

multiple sources, communication of information, citation of sources, and adherence to laws and regulations relating to information use and privacy, among other skills (ACRL, 2006; Asselin et al., 2003; Eisenberg et al., 2004; Kuhlthau, 1993; 2004; Stripling &Pitts, 1988).

Teachers in this study were not required to formally communicate the results of their 30-min search, thus skills related to communication that are identified in information literacy frameworks will not be discussed here. In addition, teachers in this study demonstrated limited synthesis of information, likely because teachers appeared to use the search largely for idea generation and the locating of resources. Organization of the information they obtained during their search would likely come on a later date when teachers were developing their lesson plans and had access to their own resources (power-points, notes, etc).

However, it should be noted that teachers in this study demonstrated the ability to actively engage with sources in multiple formats (reading, videos, animations, images) and use a number of strategies to extract information from these sources in order to meet their information needs (ACRL, 2006; Eisenberg & Berkowitz, 2000). Strategies used by some teachers included bookmarking, utilizing online storage, or subscribing to a channel on YouTube; all teachers employed note taking to extract information during the 30-min search. In particular, teachers utilized note taking to summarize key ideas or important pieces of information from sources and copy and pasted images, statistics, and large 'chunks' of text in documents that would be saved. In addition, while the nature of the web-searching task did not require teachers to formally cite their

sources, teachers recorded the website URL of any resource, image, or piece of text they copied to their notes. Thus, teachers in this study demonstrated several skills related to the effective and ethical use of information which were consistent with those outlined in information literacy frameworks (ACRL, 2006; Eisenberg & Berkowitz, 2000).

Teachers' Thinking Related to the Evaluation of Resources Found Online

This section will address themes that emerged related to teachers' thinking while evaluating resources they found online, in the aim of answering the second research question: *what are the thought processes science teachers use when evaluating resources or information from online sources?* In particular, the three major themes that emerged from teachers' web search and post-search interview statements related to resource evaluation include considerations of: (a) appropriateness for teaching context (with five sub-themes: alignment with POS, interesting or engaging to students, areas of student difficulty, materials required, and safety), (b) credibility of the resource and (c) science accuracy. Other themes that will be discussed include: (d) novelty, (e) up-to-date, (f) aesthetics or user friendliness, and (g) consideration of First Nation, Métis and Inuit (FNMI) perspectives. Each of these themes will be discussed, in turn.

Appropriateness for teaching context. One of the major themes that emerged related to teachers' evaluation of resources found online was considerations of whether a resource was appropriate for the teaching (or learning) context that the teacher had in mind during the search. In particular, teachers' took in to consideration whether a resource aligned appropriately with

the Program of Studies, would be interesting or engaging to students, addressed areas of student difficulty, if they had access to the materials required (particularly for labs or activities), and if safety was a concern. Each of these themes emerged from the analysis of teachers' post-search interview responses and think-aloud statements during the 30-min search.

Alignment with program of studies. Four teachers consulted the POS directly during their search (A, D, H, and K) and six additional teachers (C, E, F, G, I and J) made either direct or indirect references to the POS while evaluating resources during their 30-min search, or in follow-up discussion relating to resource evaluation during their post-search interview[10]. Two of the primary considerations for teachers related to the POS involved evaluating if the content of a particular resource was aligned with the POS and if the depth of coverage was appropriate for their students. During their evaluation of resources, several teachers' noted instances where terminology was out dated or not consistent with the current POS. In addition, teachers paid attention to resource complexity. Teacher A, for example, explained during her post search interview how finding resources that cover topics at an appropriate depth can be problematic:

> So it's really specific, or, you get the opposite where it's really general. So you get this sort of, simplified version that you would talk about in maybe Grade 7, or you get this hard-core, University [explanation] and there's this in-between piece for our students that is missing. Because Alberta is one of the few places that goes in to this particular depth on this

[10] Note that Teacher B did not indicate he was considering the POS during his evaluation of resources, which may be because he was conducting research for a textbook he was developing at a high-school level for a program outside of Alberta.

topic. (Teacher A, referring to the Biology 20 unit: Photosynthesis and Cellular Respiration, more specifically the 'biochemical piece')

Overall, that teachers considered whether information was related to curricular concepts and noted if information was too simple or too advanced for students has also been noted in other research on teachers' evaluation of digital resources (Recker et al., 2004).

In addition to consideration of the alignment of the content in a resource with the POS and whether there was an appropriate depth of coverage, teachers also made judgments about resources based on how they could be utilized to make connections between topics in the POS, to extend or apply the curriculum, or to teach skills emphasized in the POS. For example, in the post-search interview, Teacher H elaborated on why she saved a particular resource (statistical data on motor vehicle fatalities and injuries by age group in Canada, (Transport Canada, 2012)) she found during her search:

> I think that I can see a couple of uses for this. Number one, I think I can see putting it up there for students and discussing how these statistics reveal something interesting... and having a discussion about it. I could also see using the numbers to have students do some graphs which is a skill in Science 24 that I know that they need to practice and do. (Teacher H)

Overall, there was evidence that teachers' drew upon the POS when evaluating resources not only to make determinations of whether or not the topics addressed within a particular resource were appropriate and covered at a

reasonable depth, but also if particular resources could be used to draw connections between areas of the POS, or to emphasize skills or applications of the POS.

Interesting or engaging to students. Another factor that teachers considered when evaluating resources was whether a particular resource would be interesting or engaging to students. In total, eight teachers (C, D, F, G, H, I, J, K) mentioned engagement or interest when evaluating resources during their 30-min search, or when explaining their evaluation of resources during their post-search interview. For example, Teacher D highlighted in the post-search interview that student engagement is something he considers when evaluating resources, especially videos:

> The other big thing [I look at] is likes. More often than not, even if it's a great resource and the person might be really accurate... if the likes on it are really low, that says something about how kids perceive it as well. So it doesn't really matter if the information and content is correct, if there's like a million dislikes on it... then the kids are not going to be engaged with it. (Teacher D)

Teacher D's strategy of using the number of likes on a video or resource as an indicator of whether it would be interesting or engaging to students was also utilized by two other teachers in this study.

Teachers also used other criterion (such as visual, animated, interesting content, dramatic presentation, that students found it interesting in the past, or that the resource peaked their own interest) as ways to evaluate whether resources

would engage students. While a thorough analysis of how teachers made assessments of whether students would be engaged by particular resources was not a goal of this study, student interest was a consideration for eight out of 11 participating teachers. In addition, that teachers consider students' interest or engagement when evaluating digital resources has also been noted in other research (Recker et al., 2004).

Areas of student difficulty. Six teachers (A, E, G, H, I, K) considered areas of student difficulty while evaluating resources found online during their web search. In particular, these teachers were concerned with whether a resource would help clarify content or procedures students typically found challenging or problematic, or, conversely, if a resource would reinforce areas of student difficulty (because concepts were explained poorly, information was omitted, etc). For example, while watching a tutorial video on solving questions related to the common ion effect (ThatChemGuy, 2013), Teacher E paused the video to describe how the explanation provided could have better addressed an area of student difficulty:

> One thing I don't like is that he... although you're really supposed to X this out [motions to left side of ice table] ... kids, they get the answer of X and they still don't know what that means, so they think that's the concentration of calcium and ... not calcium fluoride. So I think I would do it differently, I would probably put an X for initial and then I would go minus X... it's just a personal thing. I just don't think they get it. (Teacher E)

Similarly to Teacher E, Teacher A considered how particular resources could address student areas of difficulty. In the post-search interview, Teacher A was asked to articulate what she was her thinking related to her evaluation of a particular resource (an animated diagram outlining photosynthesis[11]) that she found during her 30-min search. She explained:

> The first thing I looked at was the actual diagram that they had... that's the part that initially confused the students... so the way they set out their diagram shows the order really well. It shows all of the pieces in context. ...Trying to get that across to the students can be difficult, because I can't animate on the board. ...[but] this animates it. [And in this diagram] it is connected [and shows where the hydrogen comes from] so students don't think that hydrogen just magically appears and then starts producing ATP. (Teacher A)

What is evident in the statements made by both Teacher A and Teacher E and is representative of statements made by teachers G, H, I, and K, is that these teachers drew upon their teaching experience and knowledge of student areas of difficulty when making evaluations of particular resources. It should also be noted that, while these teachers' perceptions of how specific resources addressed student areas of difficulty played an important role in their overall positive or negative evaluation of that resource, each teacher only mentioned this criteria for one to two resources located during their 30-min web search.

[11] This resource was from a site (Learn Alberta) that requires a password to access. https://www.learnalberta.ca/

Materials or resources required. Seven teachers (A, D, E, G, I, J, and K) highlighted that they consider the materials or resources required when evaluating a particular resource, especially when evaluating laboratory exercises, demonstrations, and classroom activities. Most teachers considered whether they already had access to the resources required, or could obtain them. In addition, teachers considered factors such as the cost and storage of materials. For example, when asked during the post search interview to explain her thinking in relation to a lab activity (Nuffield Foundation, 2013) she found online during her 30-min search, Teacher A stated:

> I was looking through all the materials wondering if a school... and my school, in particular, would have those materials. So, was it even plausible to consider doing? And then, thinking that some of the materials would be used up... [so] whether that was realistic to purchase on a year to year basis. And could we store it? Is it worth purchasing all the materials to try something out that you don't necessarily know what the outcome is going to be... or at least what you're hoping it's going to be. Right? I've never done it before. I may have done something like this before, but is it worth it to purchase those materials to try something out? (Teacher A)

In addition to considerations such as access, cost, and storage of materials required for labs or activities, teachers also took in to account the cost of online subscriptions or other resources that could be (potentially) useful for their teaching. For example, during her web search, Teacher G was looking for lesson plan ideas and visited sites that required paid subscriptions as well as ones that

provided free resources. When prompted in the post-search interview to explain the reasoning behind her selection of resources, she highlighted cost as a factor: "...I worked in an inner city school, so I'm really aware of the resources required... and that's why with both those lesson plans that I actually liked, it didn't require me purchasing anything" (Teacher G). Similar to the results reported here, Recker et al. (2004) found that teachers were less likely to use digital resources that charged a fee. While these factors were not addressed by all teachers in the study, cost and access to resources were considered by seven of 11 participating teachers. Related to these concerns are also issues of safety, which will be addressed in the following section.

Safety. While it did not emerge as a major theme from the data, three teachers (A, J, and K) mentioned issues of safety when evaluating resources found online, specifically in reference to labs or activities. For example, Teacher K indicated she was more critical of labs or activities that were available on teachers' personal websites and had not been properly vetted, because, based on past experience, she found that these activities were sometimes safety risks and required a great deal of modification to be usable within her classroom. It should also be noted that while only three teachers made reference to safety issues in relation to the evaluation of resources, there were only four teachers (A, D, J and K) explicitly searching for labs or activities that may have required materials beyond what is typically used in a classroom setting. Thus, for teachers who were searching for lab activities, safety emerged as an important consideration in the evaluation of resources.

Credibility. The credibility of a resource was an area of consideration highlighted by all teachers in the study, making it another major theme related to teachers' evaluation of resources. That credibility emerged as a major theme considered during online research is consistent with research with non-teachers (see Porter, 2011). In this study, teachers employed various strategies when making judgments of the credibility of a resource, including: considering the source or author, evaluating the accuracy of science content, attending to the number and quality of references and utilizing cross-referencing. These findings will be related to literature on credibility evaluations in online environments, which identify five criteria that should be employed to make credibility assessments: accuracy, authority, objectivity, currency, and coverage or scope (Metzger, 2007).

Source or author. All 11 teachers demonstrated in their 30-min search or highlighted in their post-search interview that they look to the source or author of a website or resource when making evaluations about its credibility. In general, teachers highlighted that they were more likely to judge university sites, organizations focused on science education, and government-affiliated sites as credible compared to sites authored by an individual. For example, Teacher B stated he was more likely to trust sites such as "... Scientific American, NASA, basically websites that are written by accepted professionals" (Teacher B). Teacher G expressed a similar sensibility in her post-search interview: "... Discovery Channel is one that I would trust, Smithsonian, NASA... I know that the people behind them are usually people with PhD's in whatever they're talking

about." Teacher K further echoed these statements: "if it's a government or educational website, that usually has more credibility to me, than... just somebody's collection of websites." That teachers preferred well known sites with collections of learning resources, as well as professional or government sites is supported by other research (see Recker et al., 2004; Williams & Coles, 2007b). Some teachers in this study also highlighted that they took cues from the URL of a website to help determine its source and make judgments about credibility, (as was discussed in a previous section), which has been found in other studies of adults' evaluations of website credibility (Porter, 2011).

In addition, it is noteworthy that, while teachers often utilized professional or government sites during their searches and acknowledged them as being trustworthy, no teachers utilized scholarly educational literature or research during their search. While the factors related to this were not explored in this research, it may be an area of concern, as Williams and Coles (2007b) claim that teachers' "reliance on informal sources and/or more general sources of information does little to provide the kind of knowledge base needed for informed judgments about information or for the building of self-confidence in finding and using information" (p. 202).

Finally, it should be noted that while consideration of the source or author was highlighted by all teachers in this study, some teachers' responses were more thorough and provided multiple factors of consideration in determining the credibility of a source. For example, Teacher A mentioned a number of criteria she considers (that were not articulated by other teachers):

> I look at the website. Who is sponsoring the website? Do they have advertisements, and if so, why are they there... and who is publishing the information, what kind of biases do they have? I look at the author, because sometimes I know who the authors are, so you can kind of determine what their slant is. What is the slant? Is it focusing on one perspective, or is it looking at the fact that there are other[s]? (Teacher A)

Comparison of the statements of Teacher A and other teachers to the criteria outlined in credibility assessment frameworks (see Metzger, 2007) highlights that teachers in this study considered the *authority* and *objectivity* of sources. According to Metzger, authority can be assessed by "noting who authored the site and whether contact information is provided for that person or organization, what the authors' credentials, qualifications, and affiliations are, and whether the Web site is recommended by a trusted source" (p. 2079). Objectivity relates to determining the purpose of the site "and whether the information provided is fact or opinion, which also includes understanding whether there might be commercial intent or a conflict of interest on the part, as well as the nature of relationships between linked information sources" (Metzger, 2007, p. 2079). Thus, this study provides some evidence teachers were considering criteria consistent with credibility evaluation frameworks (Metzger, 2007) when making evaluations of resources; however, it should be noted there was variation between teachers in this study in relation to the number and type of criteria considered.

Science accuracy as a means of assessing credibility. The accuracy of information is another criterion identified in the literature as being related to

credibility assessments and refers to the "degree to which a Web site is free from errors, whether the information can be verified offline, and the reliability of the information" (Metzger, 2007, p. 2079). While the accuracy of science information was a factor all teachers considered during their evaluation of resources online in this study (which will be discussed in a subsequent section titled Science Accuracy), a total of five teachers (A, C, F, G and I) also used the accuracy of science information within a particular resource as an indicator of the credibility of that resource. For example, during the post search interview, teachers were asked to explain how they typically went about evaluating whether a resource is credible. Teacher C responded:

> Usually, I know something about the subject already. So, if that is true, then I usually continue and I can pick up the odds and ends of things I don't know. I kind-of get this sense of if it's true or not, based on that. (Teacher C)

Several other teachers also drew upon their science knowledge to get a sense of the credibility of a resource based on the accuracy of science content. In addition to drawing on their science knowledge, teachers also cross referenced resources to assist with determinations of credibility, as will be addressed next.

Cross-referencing. Five teachers (D, E, F, G, and H) indicated that they cross reference information with other sources when making evaluations of credibility, which has also been shown as a strategy utilized by adults in other research (Porter, 2011). For example, during the post search interview, Teacher E explained that when he finds a resource, he would typically cross-reference it with

two or three other sources (often university websites) to ensure the content was consistent (Teacher E). In his post-search interview, Teacher D highlighted a similar strategy that he used if he was uncertain about the credibility of a resource: "I'll ask colleagues... but then I'll also back it up by looking at real research. I'll actually do a library search or something like that" (Teacher D). Teacher H also indicated that on some topics, she will cross-reference with scholarly literature:

> I do find that peer reviewed material often feels more reliable to me. I didn't use Google Scholar on this search but I often do to look for things that I think I need some academic credentials on. Because I find that I have a feeling that I might know something, but I do want to see what the peer review process says about it. So I didn't use Google Scholar in this situation because of the content... [but] for other things I'll often have Google Scholar open in a tab at the same time. (Teacher D)

Overall, only five teachers' in this study indicated they would typically use cross-referencing to help make assessments of resource credibility, which may be of concern: while cross referencing was not one of the five criteria related to credibility evaluation outlined by Metzger (2007); comparison and corroboration between sources has been highlighted by other scholars (see Meola, 2004) as being a critical part of online resource evaluation.

References. Three teachers (F, H, and J) made note of the references provided by a particular resource during their 30-min search and made a connection between the references and an evaluation of credibility of the resource

(during either their 30-min search or the post-search interview). For example, Teacher F stated in the post-search interview: "so, generally if they've got stuff that's backing it up like you see lots of citations and things then [it's more credible]... I also check some citations just to see what the person said." Similarly, Teacher J looked at the reference lists of several resources he found during his 30-min search. When asked in his post search interview if that was a typical strategy for him, he replied:

> Absolutely. Yeah, I do that on Wikipedia pages too, the ones that have well developed reference lists that you can, again, click and follow along or go back and find the article, it's [evident]... there's someone that's done their due diligence there. (Teacher J).

Overall, while the consideration of references to aid in credibility judgments has been documented in other studies on adults research strategies (see Porter, 2011); this was not a strategy utilized by the majority of teachers in this study.

Science accuracy. Another major theme that emerged related to teachers' evaluation of resources was consideration of the accuracy of scientific information presented, which all eleven teachers demonstrated[12] and has been noted in other research (Recker et al., 2004). While there were some instances during the 30-min search where teachers were explicit that they were assessing the accuracy of science information (e.g. Teacher C noticed voltage sources oriented incorrectly in a video (Ben's Chem Videos, 2012)), in general, teachers only articulated that they were drawing on their science knowledge to evaluate the

[12] Note that a sub-group of teachers made a connection between accuracy of science information and the credibility of a particular resource, as described in the section titled Science Accuracy as a Means of Assessing Credibility.

accuracy of a resource when prompted to explain their thinking during the post-search interview. For example, during her web-search, Teacher A looked at a resource (S-cool, 2013) briefly, then closed the window and moved on in her search, without explaining why she made a negative evaluation of that resource. During her post search interview, she was prompted to explain what she was thinking and highlighted several issues with science accuracy and representation, including improper chemical notation, mixed notation, and content omissions (Teacher A).

Similarly to Teacher A, Teacher E was able to elaborate on his thinking related to the accuracy of science information in a particular resource during the post search interview. When Teacher E was asked to explain why he stopped a video (FlinnScientific, 2012) during his search and re-watched a particular section. He explained:

> I stopped it because he's using potassium chlorate and potassium chloride which are both extremely soluble... and I was kind of confused because they usually do really low soluble questions and then I thought to myself, is he saying potassium chloride by mistake? Is he just making verbal mistakes? And then I thought about the title... 'with a cation' ... a common cation... and I was like Oh! So the potassium is the common ion. (Teacher E)

Both of these examples are representative of the data more generally as they highlight how teachers drew upon their science knowledge to make evaluations of resources, though teachers may not have been explicitly aware they were doing so

during their web search. This will be discussed further in the section titled Teachers' Metacognition Related to Web Searching.

Novelty. While it can be stated generally that all teachers conducting the 30-min search were looking for something new to them (a resource, information, or ideas), six teachers (A, C, E, F, G, and K) specifically highlighted novelty as a factor they were considering while evaluating resources found online. Four of these teachers (C, E, F, and G) made comments about particular resources being novel (either during their search or upon reflection in the post-search interview) and three teachers (A, F, and K) made comments indicating particular resources were not novel. These teachers highlighted that, because they were experienced teachers, they often found it challenging to find ideas or resources that were different from what they already use:

> I've been around long enough that everybody comes up with a new idea and you're like yeah they came up with that like 20 years ago... so we do a lot of reinventing the wheel as teachers. So what I'm usually looking for... if I'm going to go online I'm looking for a lesson plan or a lab activity [that] is something really unusual. Something that we've never done before. That will take lots of digging. (Teacher F)

Overall, while novelty did not emerge as a major factor related to the evaluation of resources for teachers in this study, it was an important consideration for several teachers, especially those who were highly experienced and searching on topics that they were comfortable with (such as Teacher F).

Up to date. Five teachers (B, C, F, G, and H) highlighted either during their web search or post-search interview that how recently a resource had been developed was something they considered when evaluating resources. For Teacher B (who was researching information to include in a book chapter), finding up to date information was a particularly important consideration during his search. In his post-search interview, he explained:

> Your book's going to be 10 years out of date by the time it reaches the end of its life anyway... so especially in a field that changes, [like space exploration], you know... you've got to be absolutely up to date when you write something or else you're beaten before you start. (Teacher B)

For four other teachers in the study (who were using the search to prepare for classroom teaching contexts), the currency of information was also a consideration, especially for topics where new advancements have been made or where new information frequently comes available. For example, Teacher H was looking for collision statistics during her 30-min search and indicated in her post search interview that she was looking for statistics published within the last 10 years (Teacher H). Further, Teacher H indicated that finding up to date resources was something she often considered, "especially when I'm doing statistics. I mean if it's a picture of a tree I'm looking for... then I don't care if it's 20 years old" (Teacher H). Overall, Teacher H's comments reflect the sentiments of other teachers in the study as well; depending on the context and topic, there were instances where it was important to teachers' that resources were current and others where the age of a resource was not a concern. Overall, whether a resource

was up to date was not a major area of focus for teachers in this study, which is supported by other research on adults' evaluation of online information (see Fogg et al., 2003; Metzger, 2000). However, it should be noted that other research on teachers' information literacy has shown that teachers do take the currency of information in to account when evaluating resources (see Recker et al., 2004).

Aesthetics and user-friendliness. Four teachers (A, D, G and K) indicated, during either their 30-min search or their post-search interview, that they considered the aesthetics or user-friendliness of a website when making evaluations of the site. Teachers D, G and K highlighted that the organization of a website could impact their overall impression of the site. For example, during the post search interview, Teacher G indicated that if sites were difficult to navigate and resources within the site could not be located quickly, that she was less likely to use the site. Teachers A, G and K also highlighted that when looking for sites to share with students, they consider how their students may perceive the aesthetics and /or user friendliness of a website. To this end, Teacher A stated:

> If it's just for me, I don't really care about the look of a website, because I can ascertain the information... but if it's for my students, I don't want to send them to something that looks... bad... because I think they make judgements about the website's credibility based upon aesthetics, which is probably silly. (Teacher A)

Finally, Teachers G and K highlighted that if the text on a website (or within a video) was too small, it would be problematic for their classroom use, particularly if they hoped to project the resource on a screen or smart board at the front of the

classroom, where it would be difficult for students to see. Thus, while the aesthetics and user-friendliness of a site or resource was not criteria used to evaluate resources by most teachers in this study, it was an important area of consideration for four teachers. While website aesthetics was not considered by teachers in other studies of evaluation of online resources (see Recker et al., 2004), other research with teachers has found that they prefer shorter, less dense text on both web and print documents (see Williams & Coles, 2007b). In addition, other studies have found that adults take website layout and appearance in to consideration when making credibility evaluations online (Eysenbach & Kohler, 2002; Fogg et al., 2003).

Considers First Nations, Métis and Inuit (FNMI) perspectives. Two teachers (B and J) considered how particular resources or information they found during their 30-min search represented (or failed to represent) FNMI perspectives. Teacher J, in particular, spent a great deal of his 30-min search looking for ways to incorporate indigenous ways of using plants in his science class (in relation to the Grade 7 unit: Plants For Food & Fibre) and thus was particularly aware of how FNMI perspectives were represented in websites he found. For example, there was an instance during Teacher J's web search where he found a website title (Primitive Ways, 2013) to be distasteful. In his post-search interview, he explained his reaction:

> I'm just becoming increasingly sensitive to a FNMI perspective and worldview and who is sharing who's land and who's resources... and... I'm very sensitive of that now and for that to be the name of the website... they

> had a massive cross continental civilization working just fine before we arrived that's not overly primitive, in fact, taking over people and bludgeoning them and poisoning them seems pretty primitive to me. (Teacher J)

It is clear from this comment that sensitivity to FNMI perspectives played an important role in Teacher J's evaluation of resources during his 30-min search, however, it should be noted that, overall, consideration of FNMI perspectives was not a major theme that emerged related to teachers' evaluation of resources in this study.

Evaluation of resources: Section summary and comparison to information literacy standards. Overall, this section aimed to answer the second research question: *what are the thought processes science teachers' use when evaluating resources or information from online sources?* In addition, the findings described in this section also relate to skills outlined in information literacy frameworks; in particular the critical evaluation of information and sources of information, as described in Chapter 1.

Three major themes emerged from teachers' web search and post-search interview statements related to resource evaluation, as all 11 teachers made considerations of the: (a) appropriateness of a resource for their teaching context, (b) credibility of a resource, and (c) science accuracy. When making evaluations of the appropriateness of a resource for their teaching context, teachers considered alignment with the POS, whether the resource was interesting or engaging to students, if the resource addressed areas of student difficulty, what materials

would be required, and issues of safety. That teachers' considered the appropriateness of a resource for their teaching context has also been shown in other research on teachers' evaluation of resources (Recker et al., 2004).

When making evaluations of the credibility of a resource, teachers in this study considered the source or author, the accuracy of science information, the number and quality of references, and employed cross-referencing. Applying the credibility framework described in Metzger (2007), there was evidence that teachers in this study considered accuracy, authority, and objectivity in relation to credibility evaluation; though there was no evidence teachers' considered *currency* or coverage while making credibility evaluations.[13] That teachers did not vigorously apply the five criteria related to credibility when making evaluations of information quality or credibility has also been found in research with adult non-teachers (Flanagin & Metzger, 2000; Metzger, 2007; Metzger, Flanagin & Zwarun, 2003). Finally, it is worth noting that the criteria used by teachers in this study to evaluate credibility were not consistent between teachers; nor did all teachers explain their credibility evaluation criteria to the same depth, which has implications related to teachers' professional practice, as will be discussed in Chapter 5.

Other themes that teachers in this study considered while evaluating resources include: (d) novelty (six teachers), (e) whether resources were up-to-date (five teachers), (f) aesthetics or user friendliness (four teachers), and (g) consideration of FNMI perspectives (two teachers). A number of these

[13] Five teachers did consider whether resources were current (up-to-date) in their evaluation of resources, but did not connect this to credibility.

considerations have been identified in other studies of teachers' evaluation of resources (Porter, 2011; Recker et al., 2004; Williams & Coles, 2007b).

It should also be noted that a number of the factors considered by teachers related to the evaluation of resources align with those outlined in information literacy frameworks (ACRL, 2006; Asselin et al., 2003; Eisenberg et al., 2004; Kuhlthau, 1993; 2004; Stripling &Pitts, 1988). In particular, these frameworks emphasize the critical evaluation of information and sources, which involves making judgments related to accuracy, currency, authority and objectivity, among other factors (ACRL, 2006). As highlighted in this section, all teachers in this study considered accuracy of content and some teachers' took the currency of information in to account. Teachers also highlighted concerns of authority and objectivity in relation to their credibility evaluations of resources. In addition, several teachers indicated that they utilized cross-referencing to compare various sources of information in order to evaluate the reliability and validity of information, which is consistent with information literacy standards (ACRL, 2006). A few teachers also explicitly made distinctions between facts, points of view, and opinions (ACRL, 2006) and highlighted issues related to bias in their evaluation of resources (such as Teacher J's sensitivity to FNMI perspectives). Overall, teachers in this study considered a number of factors consistent with those outlined in information literacy frameworks when making evaluations of resources. However, it should be noted that teachers were not always able to fully articulate their thinking in relation to resource evaluation, which has implications

related to teachers' metacognition, which will be described in the following section.

Teachers' Metacognition Related to Web Searching

This section will describe the findings of this study in relation to the third research question: *do science teachers demonstrate metacognition (knowledge, awareness, and control of their thinking) while web searching on science topics?* Overall, there were two major findings in relation to teachers' metacognition. First, all teachers participating in this study demonstrated metacognitive knowledge and some teachers demonstrated metacognitive awareness and control. Second, there was evidence that participation in the research served as a metacognitive intervention for teachers in this study. Each of these areas will be discussed in the following sections.

Evidence of teachers' metacognition.

Metacognitive knowledge.

Reporting of results related to metacognitive knowledge. While web search and interview transcripts were coded following the framework outlined in Chapter 2 (separating three types of metacognitive knowledge: declarative, procedural, and conditional); the findings described here will not be delineated by those categories, rather presented generally as relating to metacognitive knowledge because there were very few instances where data was coded at only one of the three types of knowledge. In other words, when a teacher expressed metacognitive knowledge, their response was typically coded as representing two (or three) of the three types of metacognitive knowledge outlined in the

framework. This is exemplified in the following quote from Teacher E's post-search interview:

> To be honest, I'm not quick at absorbing information... I find if I watch them [videos] from beginning to end it will make sense but I haven't actually taken in that information properly. Like if I watch from beginning to end and tried to replicate it I might get, maybe one of the five things right... I have to... my brain has to repeat, repeat, repeat... lots. And even reading books... I just need it [repetition] to absorb the information.

This quote highlights declarative metacognitive knowledge because Teacher E expressed beliefs about himself as a learner; but also procedural metacognitive knowledge because Teacher E explained the process he uses (repetition) to achieve his learning goals.

Given that teachers' statements which demonstrated metacognitive knowledge generally reflected two or more of declarative, procedural, and conditional knowledge, the separation of these constructs for reporting of data provides little additional insight in to teachers' metacognition, overall. Thus, the focus of the subsequent sections will be to describe the overall findings related to teacher's metacognitive knowledge. Specifically, the following paragraphs highlight that while all teachers demonstrated metacognitive knowledge, teachers' ability to provide detailed descriptions of their thinking varied between tasks (for the same teacher) and varied between teachers.

Teachers' metacognitive knowledge. There was evidence that all eleven teachers participating in the study possessed metacognitive knowledge. In general,

most evidence of teachers' metacognitive knowledge was elicited during the post-search interview, in which teachers were prompted to describe their thinking at particular points during the web search (stimulated recall) or when teachers were asked more generally to reflect on how they typically go about their web searches. Most statements teachers made that were coded as metacognitive knowledge related to teachers' own thinking (knowledge of themselves as learners), as opposed to knowledge of alternative strategies they could have employed or beliefs about others (e.g. students) as learners. This is not entirely surprising, given that the focus of the interview and research, overall, was to gain insight on teachers' thinking.

Overall, there was variation between teachers in relation to how thoroughly they could articulate their metacognitive knowledge. Some teachers were knowledgeable about their own thinking and could explain their thinking clearly to the researcher, when prompted. Teacher E, for example, was very articulate in describing his thinking in the post search interview. Teacher E demonstrated metacognitive knowledge related to his learning processes generally (such as needing repetition, highlighted in a previous quote) as well as more specific metacognitive knowledge related to the types of tasks he undertook during their web search, including searching for resources, evaluating information, and note taking. For example, in the post-search interview, Teacher E clearly described his thinking process while he reads online:

> Usually when I'm reading online I'm trying to pick out the thing I'm looking for, it's not ... I'm just not throwing a hail Mary out there, I'm like

ok, I need to know about this... I don't need to know about the whole thing, I need to know about this... and then I try to find some key words... I scan... obviously you saw me go over the words but I'm really just looking for key words and if I find them then I'll go back and then I'll re-read it again.

Teacher E also demonstrated metacognitive knowledge when he explained his reasoning for taking notes while watching videos online: "because I want to chunk the information for the kids... so I have to chunk the information for myself... that allows me to memorize it better and to understand it better and that's the way my mind works too... step form" (Teacher E).

While some teachers participating in this research, such as Teacher E, could clearly articulate their thinking, other teachers had more difficulty explaining their thinking in relation to particular activities or tasks related to the web search, which may highlight a lack of metacognitive knowledge. For example, Teacher C was observed to make use of multiple browser tabs during the web search; when the researcher highlighted this during the post-search interview; Teacher C was surprised and could not explain whether that strategy was one he typically used (or why he used it). He stated: "Oh did I?...I don't know ... that's a tough one. Probably whatever I was doing there ... I would normally do... that's interesting"(Teacher C). Similarly, a few teachers had difficulty explaining their thinking related to how they evaluated the trustworthiness or credibility of websites during the post-search interview, with two teachers (C and J) initially stating they go by a 'sense' or 'gut feeling'. Upon

further reflection and/or prompting from the researcher, both teachers were able to explain their thinking more clearly and highlight factors they considered when evaluating credibility (such as reading the URL, or considering the source or author) which implies that participation in the research may have influenced teachers' metacognition (discussed in a subsequent section). Of significance here is that teachers initially struggled to explain their thinking, which may indicate that they lacked metacognitive knowledge related to web searching and evaluative strategies, perhaps because they had never consciously considered their thinking related to these tasks, prior to being prompted to do so in the post-search interview. In addition, the finding that teachers may have difficulty reflecting on and expressing their thinking is supported by other research on teachers' metacognition (Kozulin, 2005; Leou et al., 2006).

Finally, while there was variation between teachers related to metacognitive knowledge expressed (as described above), there was also some evidence that individual teachers could more thoroughly articulate their metacognitive knowledge related to particular tasks than others. For example, while Teacher J provided limited evidence of metacognitive knowledge related to evaluating credibility of resources (highlighted above), he was very knowledgeable about his thinking related to other strategies he employed during the web search. For example, in the post search interview, Teacher J explained how he utilized multiple browser tabs during his searches to help him keep mentally organized and on track:

> It's an actual aside. So I had this teacher in high school, whenever she'd go on tangents she would... actually take a step to the side. It's like taking a.. let me use the metaphor again, taking a path through the forest... I've diverted off the main path, I've diverted a little bit more, I've followed that path a little bit... and then as I close tabs I get back... so it's an organizational tool and with my ... the way that my attention span works, if I don't have that place holder...I get lost. (Teacher J)

In this quote, Teacher J demonstrates knowledge of his thinking related to his use of browser tabs. More importantly, these examples highlight that Teacher J was more knowledgeable about and could more thoroughly explain his thinking in relation to some areas than others, which is representative of the teachers in this study overall. Finally, the finding that there was variation between teachers in this study in relation to their metacognition in online environments was also a finding of previous research (Hill & Hannafin, 1996) and is supported by literature on the nature of metacognition (Schraw, 1998; Veenman et al., 2006).

Metacognitive awareness. Evidence for teachers' metacognitive awareness described in this section was drawn from the web search only, as the aim was to find instances where teachers became aware of their own thinking spontaneously (that is, without prompting from the researcher). While all teachers demonstrated greater awareness of their thinking during the post search interview than during the web search, likely due to prompting by the researcher or participation in the research more generally, this finding will be discussed in the section titled The Influence of Research Participation on Teachers' Metacognition.

When considering metacognitive awareness that occurred in real time (i.e., occurred while teachers were conducting the web search), nine of eleven teachers (A, D, E, F, G, H, I, J, K) exhibited one or more instances where they were metacognitively aware. More specifically, teachers' demonstrated spontaneous awareness of their thinking: related to their learning needs, when they experienced challenges during their search, or when they were evaluating resources, as will be described in the following paragraphs.

Four teachers (A, D, G, and K) demonstrated spontaneous awareness of their learning needs or thinking processes during the web search. For example, as Teacher G began her web search, she stated: "Ok so whenever I start something I always have to put the title in a document, just so I know what I'm researching and looking for. Otherwise, I get confused very easily" (Teacher G). Related to metacognitive awareness, this quotation highlights that Teacher G was aware of her tendency to forget her research goals and become confused. Teacher A also demonstrated metacognitive awareness during her web-search. In particular, she was aware of her thinking related to note-taking:

> so what I do is, if the link is short, I just copy it down on a piece of paper. But what I would do here is I would type in the foundation name because it is through a particular foundation, and then I would do the title and then I would search... go back and search for it later, which is maybe stupid, but... um... I can't help it, I just like paper and pen. (Teacher A)

While some teachers demonstrated spontaneous metacognitive awareness related to their learning processes during the web search, other teachers

demonstrated awareness of their thinking when they experienced a challenge during their search, such as when their search got off track, or when their search terms returned too many results or irrelevant results. These challenges seemed to spur teachers to pause and reflect on their thinking. For example, at approximately time 22 min in his search, Teacher F highlighted that he was dissatisfied with his search results and indicated he may need to change his strategy: "so we jump out of this ... and check one more page, then I might have to re-define the search, maybe ask a different question" (Teacher F). Teacher F went on to say "the problem with Google is that you've got only what everybody else is looking for, for the most part... so now I'll try this for a couple then I might switch to a different search engine" (Teacher F). Similarly, when Teacher I's search related to the topic of cellular respiration returned too many results, she began to reflect on her thinking:

> If I maybe tried 'cellular respiration' it would give me formula definition... so I could probably narrow it down. If I went to 'cellular respiration for kids'... I wonder if kids would simplify it too much. Though some of the students do need it pretty simple. (Teacher I)

Finally, Teacher G demonstrated awareness of her thinking when she started to get off topic during her search and re-focused her search: "Let's go back to finding photosynthesis. I find that I tend to get really distracted online" (Teacher G). In total, seven teachers (A, F, G, I, J, H, K) demonstrated awareness of their thinking related to a challenge they experienced during the web search.

Three teachers (A, E, I) demonstrated awareness of their thinking when

evaluating resources. For example, when Teacher A was looking at a particular lab during her search (Nuffield Foundation, 2013), she articulated her thinking related to deciding whether the resource would be valuable to her or not:

> I'm trying to decide if now I can start thinking about some of the skills and the...skills part of the POS too. Because it's really... complicated for what they're trying to do... at the same time, they would be doing a lot of lab skills, in it. And so... I think what I'm trying to decide is .. is it worth doing... Is it going to be related enough to the content piece that I won't confuse them. So I don't care about spending the time on the lab skills, but I just don't want them to then be confused about the content that we're also trying to illustrate. (Teacher A)

Similarly, Teacher E demonstrated awareness of his thinking related to evaluating a resource, when he paused a video he was watching (FlinnScientific, 2012) during the web search and stated:

> I think that one's good because ... he's using two things that are not highly insoluble. He's using two things that are extremely soluble... [at first] I was like, 'what do you mean you're going to precipitate something out with potassium? ... that doesn't make any sense'... but obviously there's just tons and tons dissolved, right? And so, kids won't get it confused with ... only dealing with low solubility silvers or leads ... it could be literally anything. I think that's why that one is good. (Teacher E)

Finally, one teacher became aware of his thinking during his search when he read a specific word that made him realize he was biasing his search to a

particular perspective: "I just ... read something sort of European like gunwale ... and I was disregarding it because it's not a first nations perspective ... that's kind of funny that I was doing that... it's another perspective" (Teacher J). In his post-search interview, Teacher J further expanded on his moment of awareness:

> I realize at that moment that I've now spent 22 minutes in trying to look for a FNMI perspective, for 22 minutes I've been... totally ignoring European and other perspectives. And it wasn't until I saw that very English word, gunwale, that I'm like... hey wait a minute.... I've created a bias in my search. So here I am looking for new ideas and mostly, First Nations ideas and local ideas, but in doing so, I'm also limiting myself. (Teacher J)

Overall, while nine teachers (A, D, E, F, G, H, I, J, K) in this study demonstrated metacognitive awareness during their web search, there were typically few instances (and only one instance for Teachers D and H) of spontaneous metacognitive awareness during the web search. When teachers in this study became aware of their thinking it was related to their evaluation of a resource (three teachers), a difficulty they experienced during their search (seven teachers), acknowledgement of their learning needs or processes (four teachers), or recognition of self-bias (one teacher).

Metacognitive control. Overall, there were few instances where teachers' demonstrated metacognitive control during their web search. Four teachers demonstrated metacognitive control once during their web search (F, H, I, J) and two teachers (A, K) demonstrated metacognitive control twice during their search.

When teachers exhibited metacognitive control, all but one of the instances were related to search strategies. In particular, these teachers became dissatisfied with the search results they had obtained and articulated an awareness of their thinking (metacognitive awareness) and then recognized that they needed to change their strategy (i.e. think differently about the problem); thereby exhibiting metacognitive control. For example, at one point during her search, Teacher H became dissatisfied when the search terms she entered returned too many results and changed her strategy in response:

> I've got too many things... so I'm going to go back to the tab that says Google homepage.... oh no... I'm going to go back to the program of studies... and try to remind myself what was really in there again. (Teacher H)

Similarly to Teacher H, other teachers that experienced dissatisfaction with their search results and exhibited metacognitive control attempted to increase the effectiveness of their searches through employing an alternative strategy such as referencing the Program of Studies, changing their search goals, or increasing the specificity of their search terms.

Finally, Teacher J exhibited metacognitive control related to his off-task behaviour during his web search. Teacher J recognized that a particular website (North House Folk School, 2013) was personally interesting to him but also contained a great deal of information that was irrelevant to his search. Teacher J acknowledged that he didn't want to "get too sucked in" by the website and recognized that it was "not helpful," and then closed the page and re-focused his

search. Overall, these examples highlight that while it was rare for teachers in this study to demonstrate metacognitive control; when they did so, it was typically related to challenges they experienced during the search.

The influence of research participation on teachers' metacognition. While investigation of the impact of teachers' participation in this study was not a goal of this research, there was evidence that involvement in the research process may have served as a metacognitive intervention for participating teachers, which has also been observed in other studies of metacognition (Thomas, 2013). More specifically, both the think-aloud web search and targeted questioning during the post-search interview served to encourage teachers to reflect on their thinking and may have increased teachers' awareness of their thinking (i.e., metacognitive awareness) overall.

Impact of the think-aloud search. During the post-search interview, some teachers indicated that thinking-aloud during the web-search made them more aware of their thinking. For example, Teacher G highlighted how speaking out loud during helped her to gain new awareness of her search process:

> I guess I never realized how much when I search ... it's become instinct rather than thinking it... like everything else I do I have to think out why I'm doing it, but for some reason when I'm searching for stuff [online] I don't think... it's not outward, right? (Teacher G)

This quote from Teacher G highlights that the think-aloud process served to make tasks that were somewhat instinctual to teachers, such as searching for resources, more explicit to them. Teacher G's statement also supports Connell's (1995)

reflections on the think-aloud process, in particular, that when individuals have significant experience with a task, their performance of the task becomes automatic and is carried out without conscious thought and, therefore, often without verbalization. Teacher J also highlighted that think-aloud process encouraged metacognitive awareness related to her search: "I think it just made me more aware of what I'm thinking about. I mean the voice is always there, but you hear the voice."

Impact of the post-search interview. In addition to the think-aloud search prompting teachers to become more aware of their thinking, the post-search interview may have also served to influence teachers' cognition and metacognition (Welzel & Roth, 1998; Thomas, 2013). In particular, questioning by the researcher and the opportunity for teachers' to watch segments of their web-search video may have drawn teachers' awareness to their thinking. While teachers were not questioned about the interview experience itself (for example, explicitly asked if they had thought about anything they hadn't thought of before, as a result of the interview (see Thomas, 2013)), there is evidence to suggest that several teachers reflected on their thinking in a way that may have been new for them. For example, Teacher C was asked during the post-search interview to explain if using multiple browser tabs was typical for him during his searches. His response indicates a new awareness of his behavior: "Oh did I? ...I don't know .. that's a tough one. Probably whatever I was doing there I would normally do... that's interesting" (Teacher C). Teacher C's response is significant because it highlights that targeted questioning during the post-search interview enhanced his awareness

of his thinking but also provides additional evidence that aspects of web-searching may be somewhat automatic for teachers. That web searching is automatic for teachers may be due to their expressed comfort level and familiarity conducting online searches (Connell, 1995), or due to a lack of metacognitive awareness related to their search process.

While there were some instances where teachers were unable to explain their thinking related to their search processes during the post-search interview (such as the example with Teacher C, above), in general, teachers offered more thorough explanations of their thinking during the interview than provided during their web search. In addition, when teachers were prompted by the researcher, they typically provided more detailed responses related to their thinking, which provides further evidence that the interview prompted teachers' metacognition (Thomas, 2013).

For example, during the post-search interview, Teacher F was asked to explain why he selected a particular website (National Physical Laboratory, 2013) from the search engine results page during his search. Teacher F was shown the search engine results page he was looking at during his search and a short section of his search video was played for him. His initial response was "Ok, so, what I'm doing there... that's a real quick filter...so... I'm not looking at titles I'm looking at the websites" (Teacher F). After four follow-up questions from the researcher, Teacher F was able to articulate that when he was looking at the SERP in that particular instance he was also: reading the URL of the websites and using them to assess credibility of the resource, looking at the organization name (National

Physical Laboratory) and highlighted that he often preferred using organizations such as standards laboratories for Physics information and examining key-words listed below each page on the SERP and determining if they matched his search goal (related to measurement) (Teacher F). While it was rare for teachers in this study to spontaneously articulate their thinking related to their search strategies and evaluation of resources, this example highlights the impact of the interview. In particular, it demonstrates how targeted questioning or prompts encouraged self-reflection and aided teachers in becoming more aware of their own thinking in online environments, which has been seen in other studies on metacognition (Leou et al., 2006; Thomas, 2013).

Teachers' metacognition: Section summary and comparison to information literacy standards. This section aimed to answer the third research question*: Do science teachers demonstrate knowledge, awareness, and control of their thinking while web searching on science topics?* Overall, there was evidence that teachers participating in this study possessed metacognitive knowledge (11 teachers), and exhibited awareness (nine teachers), and control (six teachers) of their thinking during their web search. In general, there were few instances where teachers spontaneously exhibited metacognitive awareness or control during their web searches. When considering metacognitive knowledge, there was evidence that teachers' metacognitive knowledge may vary between tasks for the same individual and may vary between teachers, which is consistent with definitions of metacognition provided in the literature (Schraw, 1998; Veenman et al., 2006). Some teachers in the study had difficulty reflecting on and

expressing their thinking, which is supported by other research on teachers' metacognition (Kozulin, 2005; Leou et al., 2006). In addition, there was evidence that participation in the research prompted teachers' to reflect on and become more aware of their own thinking, which has been found elsewhere (Thomas, 2013).

When considering the findings of this section in relation to information literacy standards, there are several implications related to the evaluation of the process and product of information gathering and use, which is a common component of several information literacy frameworks (see ACRL, 2006; Eisenberg et al., 2004; Kuhlthau, 1993; 2004). In particular, evaluation of the process and product involves making judgments about whether the information problem is solved as well as evaluating the process of problem solving (ACRL, 2006; Eisenberg & Berkowitz, 2000). In relation to determining whether the information problem was solved, it is difficult to evaluate the extent to which teachers met their own search goals, however, all teachers indicated in the post-search interview that they were satisfied with the results of their search, overall.

Evaluation of the process of information seeking requires reflection on efficiency (time and effort spent on the task) as well as areas of strength and difficulty related to the learning process (ACRL, 2006; Eisenberg & Berkowitz, 2000). Thus, evaluation of the process involves aspects of metacognition, because it requires learners be self-aware of their learning process, make evaluations of their process, and attempt to make changes that will support their learning. As was described in this section, there were few instances where teachers in this study

exhibited metacognitive awareness or control during their web searches. As such, this study provides some preliminary evidence that teachers may not have adequate skills related to judgement of their learning process, as defined information literacy frameworks (ACRL, 2006; Eisenberg & Berkowitz, 2000).

Chapter Summary

As outlined in this chapter, the major findings of this study relate to science teachers' cognition and metacognition while searching online. In particular, major areas of discussion included the thought processes utilized by teachers when searching online, those related to teachers' evaluation of resources and teachers' metacognition.

Related to online searching, there was evidence that the majority of teachers drew upon their science knowledge and past teaching experience to help them generate and refine search terms. Teachers also utilized the Program of Studies, Wikipedia, and autocomplete to assist them with the generation of search terms. Teachers employed multiple web browser tabs to help organize or cross-reference their searches. In addition, teachers demonstrated the ability to engage with information in multiple formats and utilized note taking to summarize key ideas or important pieces of information, which are skills outlined in information literacy models (ACRL, 2006; Asselin et al., 2003; Eisenberg et al., 2004; Kuhlthau, 1993; 2004; Stripling &Pitts, 1988). There were also some potential areas of deficiency related to teachers' searching, in particular, teachers' did not employ multiple means of gathering information online (teachers used Google

exclusively) and did not search for scholarly education literature, which has been found elsewhere (Williams & Coles, 2007b).

When evaluating resources they found online, teachers considered a number of factors, with the three major factors being: the appropriateness of the resource for their teaching context, the credibility of the resource, and accuracy of information. That teachers' considered the appropriateness of a resource for their teaching context has also been shown in other research on teachers' evaluation of resources (Recker et al., 2004). In addition, making evaluations of credibility and accuracy of information are highlighted as important skills information literacy models (ACRL, 2006; Eisenberg et al., 2004) and have been identified as criteria considered by adults in other research (Fogg et al., 2003; Porter, 2011). Additional factors considered by teachers in this study when evaluating resources include: novelty, whether resources were up-to-date, aesthetics and user-friendliness, and sensitivity to FNMI perspectives.

Related to teachers' metacognition, there was evidence that all teachers participating in this study possessed metacognitive knowledge and some teachers exhibited awareness and control of their thinking during their web search. The metacognitive knowledge expressed by teachers varied between tasks for individuals and varied between teachers in the study. In addition, there were few instances where teachers spontaneously exhibited metacognitive awareness or control during their web searches, and some teachers had difficulty reflecting on and expressing their thinking, which has been found in other research (Kozulin, 2005; Leou et al., 2006). Finally, there was evidence that involvement in the

research acted as a metacognitive intervention for teachers; that is, it prompted them to reflect on and become more aware of their own thinking, which has been noted elsewhere (Thomas, 2013). The implications of these findings will be further discussed in Chapter 5.

Chapter 5

Conclusions

Purpose and Questions

This research aimed to explore how science teachers go about searching for and evaluating information and resources in online environments, with a particular emphasis on better understanding the strategies, cognition and metacognition employed by teachers. While there is considerable support for the instruction of information literacy and web searching skills across curricula (Allen, 2007; Grafstein, 2002; Smith, 2013; Williams & Wavell, 2007), previous research indicates that students continue to have deficiencies related to searching for and evaluating information (Adams, 1999; Barranoik, 2001; Branch, 2003a; Julien & Barker, 2009; Mason & Boldrin, 2008). In addition, there is evidence to suggest that teachers may not have an adequate understanding of information literacy models or be prepared to support students' development of information literacy skills (Duke & Ward, 2009; Williams & Wavell, 2007), or metacognition (Thomas, 2012b; Zohar, 2004). Teachers are expected to model effective web searching and evaluative skills for students, however, little is known about the thinking and strategies teachers actually employ within online environments, especially within subject specific contexts. Thus, this study sought to investigate how teachers go about searching for and evaluating information online, with particular attention to exploring teachers' cognition and metacognition.

Findings and Significance of Study

This section will synthesize the major findings of this study in relation to the study's three research questions and highlight the broader significance of these findings to researchers, teachers, and students.

Findings related to science teachers' thinking when searching for information or resources online. The teachers in this study employed multiple strategies during their web searches. When generating search terms, teachers drew primarily on their science knowledge and past teaching experience, but also utilized the Program of Studies and, to a lesser extent, Wikipedia or features of the search engine (autocomplete) to assist them. That teachers in this study drew upon specialized knowledge (related to teaching, science, or both) is significant because it highlights the subject and context-specific nature of information literacy (Grafstein, 2002) and web searching skills. Additional findings related to teachers' search strategies highlight that teachers demonstrated some skills outlined in information literacy frameworks,[14] such as the ability to select sources that are suitable to their information needs. However, teachers in this study also demonstrated areas of deficiency related to information literacy skills. In particular, many teachers did not demonstrate use or consideration of many potential sources of information online (including multiple search engines, online library systems or resource collections) and no teachers searched for scholarly education literature. This finding supports previous research that highlights that teachers may lack some information literacy skills related to locating information

[14] Such as those outlined in the Big6™ Skills Model (Eisenberg & Berkowitz, 2000), as well as standards out lined by the Association of College and Research Libraries (ACRL, 2006), as described in Chapter 1.

(Duke & Ward, 2009; Williams & Coles, 2007a; 2007b). Recommendations related to this finding will be discussed in the section titled Areas for Future Research and Action.

Findings related to science teachers' evaluation of resources online. Three major factors emerged from the data related to teachers' evaluation of information or resources in this study. In particular, all teachers considered the appropriateness of the information or resource for their teaching context, the credibility, and the accuracy of information presented. While teachers drew upon a number of factors to assess appropriateness for teaching context, credibility, and accuracy, these factors varied among teachers; that is, there was not a consistent approach used by teachers in this study related to the evaluation of information online. In addition, a number of other criteria were utilized by some, but not all, teachers in the study to make evaluations of resources, including: novelty, the aesthetics or user-friendliness, whether resources were up to date, and whether information presented was sensitive to FNMI perspectives. Comparison of the findings from this study to other research highlight that while some factors teachers' considered during the evaluation of online resources are consistent with information literacy or resource evaluation frameworks (Eisenberg & Berkowitz, 2000; Metzger, 2007)[15] and the criteria used by other adults making online resource evaluations (Fogg et al., 2003)[16], there are also criteria employed by

[15] Criteria outlined in these frameworks that were demonstrated by teachers in this study include consideration of: the accuracy of information, credibility, whether a source was up-to-date (current), and the authority of a source.

[16] Fogg et al., (2003) identified the following criteria that were related to online resource evaluation for general users (which were also demonstrated by teachers in this study): design look (aesthetics), accuracy of information, name recognition and reputation (familiarity with

teachers that are not considered by other users (Porter, 2011; Recker et al., 2004; Williams & Coles, 2007a; 2007b).[17] This finding is significant because it provides evidence that while some skills related to information literacy and information evaluation can be generalized across tasks, others are context specific (Grafstein, 2002; Metzger, 2007). It should also be noted that this research extends previous research related to teachers' information literacy and web searching skills because it drew out themes based on data generated during actual web searches conducted by teachers, rather than relying on teachers' self-reports of their behaviors obtained through interview or survey (see Recker et al., 2004).

While this work acknowledges that information evaluation is a subjective process (Metzger, 2007), that teachers in this study utilized different criteria upon which to base their subjective judgments has implications for both teachers and students. First, resources or information judged by one teacher to be of quality for educational use may not be judged similarly by other teachers (and may be poor quality, overall). Second, if science teachers are instructing information literacy skills in their classrooms, students may be learning inconsistent (or incomplete) criteria for resource evaluation from their teachers. Recommendations for future research and action related to teachers' resource evaluation will be discussed in a subsequent section.

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resource), past experience with a site, identity of site sponsor (source considerations), and readability (user friendliness).

[17] In this study, teachers' consideration of a number of factors labelled under "Appropriateness for Teaching Context" (including alignment with POS, interesting or engaging to students, materials or resources required, if the resource addressed areas of student difficulty, and safety), as well as consideration of FNMI perspectives were not documented in literature with non-teachers.

Findings related to teachers' metacognition. Overall, this study found variation in the metacognition expressed by teachers in online environments, which is supported by previous research (Hill & Hannafin, 1996). Some teachers demonstrated knowledge, awareness, and control of their thinking (all three aspects of the metacognitive framework utilized in this study) and were able to clearly articulate their thinking to the researcher. Other teachers provided little evidence of metacognition during their 30-min web searches, or post-search interview, overall. These findings are supported by previous research on teachers' metacognition that indicate that teachers may have difficulty reflecting on and expressing their thinking (Kozulin, 2005; Leou et al., 2006). In addition to variation between teachers, this study found variation in the metacognition expressed by individual teachers, depending on the type of activity or thinking they were undertaking. For example, a particular teacher may have been able to more clearly articulate their thinking during their evaluation of a resource than during their generation of search terms. Taken together, these findings highlight that teachers may need training or support to enhance their metacognitive knowledge, awareness, and control related to online searching tasks, such that they can employ more effective search strategies and enhance their ability to explain their thinking to students.

Finally, another major finding of this study is that participation in the research appeared to serve as a metacognitive intervention, which has been reported elsewhere (Thomas, 2013). This finding has significance for both researchers and teachers. First, this study provides further evidence that

researchers, especially those targeting cognition and metacognition, must be attentive to the ways in which their research methods (such as think-aloud protocol and interviews) can influence participants' thinking (Thomas, 2013). Related to teachers, this study highlighted that through questioning and stimulated recall, teachers were able to provide more thorough explanations of their thought processes than they exhibited spontaneously. This implies that professional development which encourages teachers to engage in self reflection related to their online searching may help teachers to become more aware of their own strategies and thought processes (see Leou et al., 2006) and may better prepare teachers to explain their thinking to students. Specific recommendations related to teacher training and professional development are outlined in the section titled Areas of Future Research and Action.

Limitations

There are several limitations of this study. First, the sample size was small and consisted entirely of teachers with five or more years experience, thus the results of this research cannot be generalized to a wider population of teachers. Second, it is important to note that a single, 30-min web search may not provide data that is representative of a teacher's typical thinking and can provide only a snapshot of a teacher's cognition and metacognition within a specific context. In addition, there are multiple factors that may play a role in the cognition and metacognition expressed by an individual in an online searching context. Such factors may include teaching experience, knowledge of the science content they are investigating, familiarity and comfort level with online environments, as well

as motivational and affective factors (Hill & Hannafin, 1996; Hofer, 2004; Tsai & Tsai, 2003). These factors were not controlled for in this study, which could be considered a limitation. In addition, while an aim of this study was to approximate, as closely as possible, teachers' typical experience of online searching, teachers conducted their searches on a computer in a location different from what they typically used, which may have altered their online searching experience. Teachers' search experience may have also been disrupted by the researcher being present in the room and by being required to think-aloud (Hacker & Dunlosky, 2003). Despite these limitations, however, the think-aloud procedure provided insight in to teachers' thinking that would not have been possible through other means (Anderson et al., 2009**;** Veenman et al., 2006). In addition, it should be noted that all teachers indicated in the post-search interview that they felt the search approach they utilized while participating in the research was representative of their typical searches for science information or resources.

Finally, there was evidence the think-aloud procedure and post-search interview employed in this study prompted teachers to think about their thinking. The post-search interview, in particular, acted to stimulate teachers' metacognition due to targeted questioning and prompts related to teachers' thinking. This means that one of the main constructs under investigation, teachers' metacognition, may have changed as a result of participation in the research. This has been acknowledged in other literature relating to research on cognition and metacognition (Thomas, 2013; Welzel & Roth, 1998) and while it is a limitation

of this type of study, it has the potential to benefit research participants by making them more aware of their thinking, as described in a previous section.

Areas of Future Research and Action

Future research. Given the findings of this study and the limitations identified in the previous sections, there are several areas of future research that could build upon this work. First, to address issues related to the lack of generalizability of this study, future research on teachers' search strategies should be conducted with larger samples of teachers throughout a larger geographic area. Increasing the number of web-searching sessions or recording teachers' online behavior for longer periods of time would also help enhance the reliability of data. In addition, because teachers in this study were relatively experienced, it may be worthwhile to investigate the search strategies employed by teachers at a variety of experience levels. Thus future research could help determine if teachers' search strategies are influenced by their level of teaching experience, level of experience using the web, subject area knowledge, confidence, self-efficacy, or other factors. Further, while this study was exploratory in nature, future research could aim to investigate whether expanding teachers' knowledge of information literacy models enhances the sophistication of strategies employed by teachers in online environments. An interesting finding was that majority of teachers in this study indicated they would not be interested in undertaking professional development related to web searching. Future research should investigate factors that may influence teachers' interest in pursuing professional development related to web searching. Finally, while this research provided insight in to the thinking and

strategies employed by science teachers while conducting their own searches for science information, a logical continuation of this work would be to investigate if and how teachers communicate their thinking to their students, model effective online learning for their students, and support students' development of information literacy skills.

Future action. While there was variation in the search strategies, evaluation criteria, and metacognition employed by teachers in this study, professional development related to these areas would likely benefit all teachers in this study. Interestingly, while no teachers in this study had ever undertaken professional development specifically related to web searching in science; only two teachers indicated they would be interested in future professional development and three additional teachers indicated they may or may not be interested, depending on what was offered. An important area of future action, therefore, would be to find means to encourage teachers to engage in professional development in this area, perhaps by highlighting negative consequences of misinformation online (Metzger, 2007) and by identifying benefits related to having effective information literacy skills and adaptive metacognition.

Another recommendation from this study is that pre-service and in-service teachers be offered professional development related to web searching and evaluation that incorporates aspects of metacognition and is specific to their subject area. An integrated framework should be developed which incorporates general skills related to information literacy as well as those specific to searching for and evaluating science information and those related to searching for and

evaluating science teaching resources. This framework could be presented to teachers as a means to reflect on and expand their online searching and evaluative skills and to increase dialogue between teachers related to online searching practices. This framework would not be intended to serve as a checklist of steps to follow, as these types of checklist models may "promote a mechanical and algorithmic way of evaluation that is at odds with the higher-level judgment and intuition that we presumably seek to cultivate as part of critical thinking" (Meola, 2004, p. 337). In addition to encouraging teachers to engage in dialogue and self-reflection related to their web searching and evaluation (which may help them develop their metacognition), future professional development for teachers should also emphasize the importance of having adaptive metacognition. In particular, teachers should be made aware that by developing knowledge and awareness of their own thinking in online environments, they will be better able to model and explain their thinking for their students (Boekaerts, 1997; Zohar, 2004).

Closing Remarks

Given the ever-expanding availability of information online, it is critical that teachers are able to search for, retrieve, and effectively evaluate information from online sources. These skills are necessary so that teachers are prepared to engage in continuing development of their professional practice and can serve to effectively instruct and model these skills and ways of thinking for their students. This exploratory study highlighted that science teachers employ diverse thinking related to searching for and evaluating information in online contexts and that teachers may vary in their level of knowledge, awareness, and control over their

thinking in online environments. The results of this research could assist teachers to gain an increased understanding of effective web searching skills and strategies and begin to address a gap in the literature related to teachers' information literacy, web searching skills, and metacognition.

Appendix A

Teachers' search goals and search terms utilized

Table A1
Teachers' Search Goals Coded by Topic

	Teacher										
Search Goals	**A**	**B**	**C**	**D**	**E**	**F**	**G**	**H**	**I**	**J**	**K**
Goals Related to Instruction or Pedagogy											
Generic Resources (did not specify)	X			X							
Project / Activity	X						X			X	X
Lab (Lab ideas)	X			X				X		X	
Lesson Plans							X				
Questions					X						
Supplemental Material for students				X					X		
Animations					X			X			
Videos							X	X			
How to explain a topic / concept					X						
Content Goals		X	X		X	X		X			

Detailed Descriptions of Teacher's Search Goals and Terms

A1. Teacher A

Science course related to 30-min search: Bio 20

Lesson / Unit: Photosynthesis / Cellular Respiration

Teacher goals for Search:

- better resources related to photosynthesis / cell respiration. Applicable if students miss class (i.e. content aligned more appropriate with the POS).
- interesting projects / labs to illustrate the more 'biochemical' pieces.

Teacher A: Record of Search Terms		
Time Stamp (mm:ss)	Search Term	Site
0:10	alberta science programs of study	google
2:20	learn alberta	google
2:40	photosynthesis	Learn Alberta
12:20	celluler respiration	Learn Alberta
12:40	cellular respiration	Learn Alberta
13:35	photosynthesis lab	google
15:00	photosynthesis lab and biochemistry	google
17:30	light dependent reaction of photosynthesis lab	google
24:35	light independent reaction of photosynthesis lab	google
29:10	photosynthesis project ideas	google

A2. Teacher B

Science course related to 30-min search: for a book to sell outside Alberta

Lesson / Unit: Astronomy - theories of cosmology

Teacher goals for Search**:** Looking for background for a section on cosmology. This is at a high school level.

Teacher B: Record of Search Terms		
Time Stamp (mm:ss)	Search Term	Site
1:15	cosmology	google
3:13	why is the sky dark	google
5:27	what can we conclude with the fact that the sky is dark	google
8:28	what can't the universe look kike	google
10:00	google.ca	google
10:20	shape of the universe	google images
20:15	timeline of cosmological theories	google
24:56	native american cosmological theories	google
27:50	archaeoastronomy	google
29:30	stone circle	google
30:25	medicine wheel	google images

A3.Teacher C

Science course related to 30-min search: Physics 30

Lesson / Unit: Atomic Physics

Teacher goals for Search: More background information on discovery of the atom and nucleus.

Teacher C: Record of Search Terms		
Time Stamp (mm:ss)	Search Term	Site
0:45	dalton's atomic model	google
5:31	[types in: youtube.com]	
5:41	dalton atomic theory	YouTube
10:04	[types in: google.com]	
10:09	thomson	google
10:26	jj thomson	google
12:45	[types in : youtube.com]	
12:50	charge to mass ratio of an electron	YouTube

13:20	thomson charge to mass ratio of an electron	YouTube
25:38	[types in: google.com]	
25:45	rutherford	google
26:00	ernest rutherford gold foil	google

A4. Teacher D

Science course related to 30-min search: Bio 30 - AP

Lesson / Unit: Unit C + Unit D

Teacher Goals for Search:

Resources for Bio 30AP labs. School I am teaching at is starting Bio 30 AP next year and require some resources to be developed. I will look at what has been done previously and what will be needed for next year's classes. Finding online resources that can be used / added to science websites that students can gain access to.

Teacher D: Record of Search Terms

Time Stamp (mm:ss)	Search term	Site
0:25	biology 30 program of studies	google
1:40	[types in: www.youtube.com]	
2:50	gel	Alberta Education Biology 20-30 Program of Studies
3:14	biology 30 AP resources	google
3:35	biology 30 AP labs	google
4:15	gel elect	pdf document: Biology AP 35-5 (Rocky View School Division)
4:25	labs	pdf document: Biology AP 35-5 (Rocky View School Division)
5:35	biology 30 ap gel electrophoresis lab	google
13:40	www.ualberta.ca [clicked quick link]	
14:15	sigalet	Pub Med
26:30	gel electrophoresis	YouTube - Bozeman Biology Channel

A5. Teacher E

Science course related to 30-min search: Chem 30 AP

Lesson / Unit: Kinetics, Equilibrium

Teacher Goals for Search: Learn about a topic I am not 100% confident in. Looking for animations, questions, and different ways of explaining the topic (Kinetics).

Teacher E: Record of Search Terms		
Time Stamp (mm:ss)	Search term	Site
0:12	ksp	google
0:19	KSP sol (clicked on KSP solubility product)	google
2:50	common ion effect	google
11:39	youtube	google
11:44	common ion effect	YouTube

A6. Teacher F

Science course related to 30-min search: Physics

Lesson / Unit: Physics 20 mass and force, Physics 30 Atomic

Teacher Goals for Search: Find more information relating to definition of mass and force.

Teacher F: Record of Search Terms		
Time Stamp (mm:ss)	Search Term	Site
0:22	mass and force	google
7:10	von klitzing resistance	google
23:30	Higgs Boson and	google
24:15	Higgs field and	google

A7. Teacher G

Science course related to 30-min search: High school

Lesson / Unit: Photosynthesis (E.T.C.)

Teacher Goals for Search: Find resources: lesson plans, videos, games, activities

Teacher G: Record of Search Terms		
Time Stamp (mm:ss)	Search Term	Site
1:00	photosynthesis images	google
3:48	kids discover photosynthesis	google
5:35	symbaloo	google
7:08	electron transport chain videos	google
11:47	[types in: google.ca]	
11:50	[types in: google.com]	
12:01	electron transport chain lesson plans	google.ca
14:00	electron transport chain lesson plans high school	google.ca
18:00	wikipedia	google.ca
18:10	electron transport chain	Wikipedia
22:30	oxidative phosphorylation video	google.ca
26:10	[types in: google.ca]	
26:11	3D ME Creative Studio	google.ca
29:40	electron transport chain 3D model	google.ca
30:15	electron transport chain activities for students	google.ca

A8. Teacher H

Science course related to 30-min search: Science 24

Lesson / Unit: Transportation Safety

Teacher Goals for Search:

- find resources that are applicable to student interest
- find resources to guide process skills
- find lab ideas
- clips / animation of concept
- recent information / statistics.

Teacher H: Record of Search Terms		
Time Stamp (mm:ss)	Search Term	Site
0:20	alberta program of studies science 24	google
4:35	[types in: google.ca]	
4:45	highway safety statistics for alberta	google
15:30	causes of death or injury in Canada	google
20:45	causes of death or injury in Canada adults and teenagers	google

A9. Teacher I

Science course related to 30-min search: Biology 20

Lesson / Unit: Cellular Respiration

Teacher Goals for Search: Find information for students to use to supplement modules

Teacher I: Record of Search Terms		
Time Stamp (mm:ss)	Search Term	Site
0:18	cellular respiration	google
4:33	cellular respiration	google
4:47	[same search term, "cellular respiration" but she clicked google images]	google images
6:28	[same search term "cellular respiration" but clicked back to google search]	google
11:55	cellular respiration for kids	google
18:30	cellular respiration self quiz	google
23:35	cellular respiration quiz	google
23:40	cellular respiration and photosynthesis quiz	google
24:22	cellular respiration test	google
24:32	cellular respiration test pdf/	google
27:05	cellular respiration quiz	google
29:09	cellular respiration diagrams	google
29:20	cellular respiration diagram worksheet	google

A10. Teacher J

Science course related to 30-min search: Science 7 & 8 (maybe 6)

Lesson / Unit: 7 - Plants for Food + Fibre. 8 - Simple Machines.

Teacher Goals for Search: I'm trying to make some science units and concepts more hands-on and will be looking for labs and information to make labs. Food + Fibre - wise I want to address the concepts related to how plants are used (fibre for fabrics, food for crops, etc. For 8 - I'm always interested in finding practical activities to demonstrate physics concepts and machine systems something along the lines of roller coaster-ology or siege engines that can be built and rebuilt as an extension of what is learned in Gr 7 structures and forces.

Teacher J: Record of Search Terms		
Time Stamp (mm:ss)	Search Term	Site
0:30	tie dye with berries	google
2:15	first nations plant dyes	google
5:28	turmeric	google
6:00	indigenous cabbage	google
6:32	north american indigenous cabbage	google
10:15	sources for cedar bark	google
10:35	sources for cedar bark for weaving	google
10:51	cedar bark for weaving	google
11:24	order cedar bark for weaving	google
11:43	order bark for weaving	google
11:56	order bark for weaving	google
12:00	order textile bark	google
13:10	vancouver order cedar	google
14:36	canadian canoe museum	google
16:05	model dugout canoe	google
18:35	birch bark canoe model	google
21:15	birch bark canoe model canada	google
22:15	historcial types of canoe	google
28:12	canada paddle blanks	google
28:45	blank	http://greyowlpaddles.com/
29:41	order paddle blanks	google

A11. Teacher K

Science course related to 30-min search: Biology 30

Lesson / Unit: Nervous System / Endocrine System

Teacher Goals for Search: Looking for activities that compliment this unit.

Teacher K: Record of Search Terms		
Time Stamp (mm:ss)	Search Term	Site
0:11	alberta education program of studies	google
0:57	[types in: google.com]	
1:02	nervous system activities for high school	google
2:13	nervous system	Biology20/20 POS
6:40	brain activities for high school students	google
11:09	understanding the eye activities	google
16:28	understanding the ear activities	google

20:11	endocrine system activities	google
22:08	2learn	google

Appendix B

Sample Post-Search Interview Questions

General Questions about online searching in science:

1a. In an average week, how much time do you typically spend online looking for information or resources related to your science teaching?

No time Less than 1 hr 1-3 hours 3 - 5 hours More than 5 hours

1b. is this different during the school year than summer or when you are not instructing?

2. Compared to other ways of learning about science / finding science resources (TV, newspaper, radio, magazines, books), how does the internet 'rank' for you? (Do you use it most often, least often, or somewhere in the middle?)

3. How confident do you feel when you are using the internet related to your teaching practice?

4a. Have you received any training or taken part in any professional development related to finding science information or resources online? (Ex search strategies, particular web-resources, etc?)

b. Would you be interested in doing so?

5. What are you normally looking for online in relation to your teaching practice? (Labs, activities, lesson plans, content?)

6a. How often would you say that you find what you are looking for online?

Rarely Sometimes Usually Always

6b. Explain your answer:

7. How do you generally decide whether you 'trust' some science information or resource you find online?

8. How do you decide if a resource / information is of quality?

9. Do you ever look for .org, .com, .edu?

10. Do you ever use Wikipedia for science info? Why or why not?

Questions about the 30-min search

1. What were you trying to accomplish during your 30-min search?

2. How did the search go for you? (Did you find what you wanted?)

3a. How comfortable / familiar were you with the subject area you were investigating in your search?

3b.Would your approach be different if you were more / less familiar?

4. I noticed some things that you did during your search: Would you say this search is similar to the way you 'typically' do things, in terms of strategies used?

(Please explain how it is similar or different). *(Specific questions would relate to teacher - for example "you used google")*

5a. The computer (PC) was set up with Firefox as the default browser and google as the default search engine. Are these typical for you? (What do you normally use?)

5b. did these cause any issues for you?

6a. Are there any other ways in which the set-up for the 30-min search is different from your typical set-up?

6b. was your search a-typical from what you normally do in any way?

7. Did you encounter any obstacles during your search? (If so, please describe them).

Specific Questions about the Search

Note that these are sample questions only - questions would have been tailored to individual teachers.

1. At 1:40 in your search, you mentioned you really liked this page. Can you elaborate on why this was a good resource for you? [Shows teacher resource and/ or video segment]

2. At 2:30 in your search, you selected this resource [provide link] from the search engine results page. Can you elaborate on why you selected that resource from the SERP? [Shows teacher resource and video segment]

3. At 4:00 you refined your search. Can you explain that? [Shows video segment]

Appendix C

Coding Scheme Related to Metacognition

Table C1

Metacognition Coding System and Examples

Category	Definition	Example
Declarative Metacognitive Knowledge	Knowledge about cognitive strategies, beliefs about one's self or others as learners, beliefs about particular learning tasks.	"...the first time I go look for something, I very often end up in the same place... I download a bunch of stuff and then never go back and look at it, kind of thing. Then that percolates in my mind... that's why I'm so absent minded, and then all of a sudden you know you get an idea of maybe I could do this..." (Teacher B talking about his search process in the post-search interview; also coded at procedural metacognitive knowledge).
Procedural Metacognitive Knowledge	Knowledge about how to perform a cognitive task; the processes employed to achieve learning goals.	"To be honest, I'm not quick at absorbing information... I find if I watch them [videos] from beginning to end it will make sense but I haven't actually taken in that information properly. Like if I watch from beginning to end and tried to replicate it I might get, maybe one of the five things right... I have to... my brain has to repeat, repeat, repeat... lots. I'm not one of those people who hears it once and knows it forever.. I 'm not even close to that... and even reading books, even for enjoyment... quite often I'll read a whole page and then be like... what did I read? Like do you know what I mean? So... I just need it [repetition] to absorb the information." (Teacher E describing his learning processes in the post-search interview; also coded at Declarative Metacognitive Knowledge).

Category	Definition	Example
Conditional Metacognitive Knowledge	Knowledge about 'what to do when'.	"I was thinking about this... the way that I look for resources changes based on how soon I need to use that lesson idea. So the stuff I was looking for yesterday, that would be the search that I would do... sort of in a typical summer or at a vacation before a unit starts. So it's the dreaming type, resource gathering to try to figure out... here's a concept that when I've taught the topic or did a lab activity I wasn't happy with how it went, so what else could there be? So doing that sort of... I'm just sort of putting out feelers for ideas so just to be like, is what I'm thinking of totally possible or not?" (Teacher J, describing in his post-search interview how context influences the way he goes about his web searches.) (Also coded at declarative metacognitive knowledge; procedural metacognitive knowledge.)
Metacognitive Awareness	Monitoring of cognitive processes. (Often exhibited by engagement in 'self talk').	"But I'm trying to decide if now I can start thinking about some of the skills and the... like the skills part of the POS too. Because it's really... like it is complicated for what they're trying to do... at the same time, they would be doing a lot of lab skills, in it. And so... I think what I'm trying to decide is .. is it worth... Is it going to be related enough to the content piece that I won't confuse them. So I don't care about spending the time on the lab skills, but I just don't want them to then be confused about the content that we're also trying to illustrate." (Teacher A, demonstrating awareness of her thought process related to the evaluation of a resource during the web search.)
Metacognitive Control	Regulation of cognition.	"And then I'll probably look at this and say... ok, you need to be way more specific. And I'm going to say 'photosynthesis lab and biochemistry'. [refines search terms] Because I'm wanting the biochemistry piece, not just the sporing piece. " (excerpt from Teacher A's web search transcript; Teacher A changed her search strategy after evaluating her previous strategy / thinking and the results of her search.) (Also coded at metacognitive knowledge and awareness)

Appendix D

Coding Scheme Related to Teachers' Actions and Thinking

The codes outlined in Table D1 were used to code the web-search video and calculate duration of time each teacher spent on each action. The codes in Table D2 were used to code teachers' web-search transcript and post-search interview transcript.

Table D1

Codes Related to Teachers' Actions

Code	Description
Closing Windows or Moving Out of a Site	-closing tabs in the browser or hitting the 'back' button within the site
Examining Images In Website	-looking at an image
i) Website Exploration or Reading	-reading text or looking at graphics on a website
ii) Evaluating Results Within a Webpage	-evaluating a 'list' of links or resources that are provided on a website (similar to a SERP)
iii) Taking Online Quiz	-taking a quiz online
Logging In	-logging in to email, online storage, or a password protected website
Other	-asking the researcher a question or commenting to the researcher
Program of Study	-on the program of study website / within a POS document
Search Engine Page - Entering Search Terms	-typing in search terms in a search engine page
Search Within Document or Site	-typing in search terms within a document or website
Search Engine Results Page	-looking at results on a search engine results page
Typing in URL or Direct to Site	-typing the URL of a website in or utilizing a quick link or bookmark to go to a site directly
Watching Video	-watching a video online
Writing Notes	
i) Writing Notes on Computer	-writing notes using word, notepad, or some other means utilizing the computer
ii)Writing Notes on Paper	-hand writing notes
Consulting Own Resources	-looking at resources / plans already created by the teacher
Organization	-re-ordering files, re-naming files, etc.
Saving Resource or Document	-bookmarking or downloading files from the web

Table D2

Codes Related to Teachers' Thinking

Code	Description
Aesthetics and user friendliness	- comments that relate to aesthetic / user friendliness of the site / resource
Appropriateness for teaching context	-statement that relates information to teaching context (contains sub categories):
i) Alignment with POS	-comment highlights consideration of whether a resource is aligned with POS outcomes
i) Interest / Engagement	-comments that highlight consideration the interest or engagement of students
iii) Areas of student difficulty	-comments indicate consideration of areas of student difficulty
iv) Materials or resources required	- statements related to materials required to undertake a lab / activity / lesson
v) Safety concerns	- highlights issues of safety
Credibility	-comments related to the credibility of a resource
Expression of comfort with subject area	-teacher expresses comfort (or discomfort) with their knowledge of the subject area
Familiarity with resource	-comment that indicates the teacher is familiar with / recognizes the resource or source
FNMI	-consideration of FNMI (First Nations, Métis and Inuit) perspectives
Images	-comments relating to images
Judgment of resource (Evaluation)	-comments related to teacher's evaluation of a resource (positive or negative)
Labs or Activities	-comments relating to labs or activities
Research Constraints	-comments that highlight methodological constraints of the research

Code	Description
Search term - Generation	-comments related to the generation of search terms
Search term - Refinement	-comments related to the refinement of search terms
Note taking	-comments related to note taking
Novelty	- highlights that a piece of information or resource is new to the teacher
Up-to-date (timeliness)	- considerations of how recent or up-to-date a source of information or resource is
URL	- comments that highlight consideration of the URL or reference to the URL of a site
Videos	-comments relating to videos
Wikipedia	-comments relating to use of Wikipedia

Appendix E

Web Browser and Search Engines Utilized by Teachers

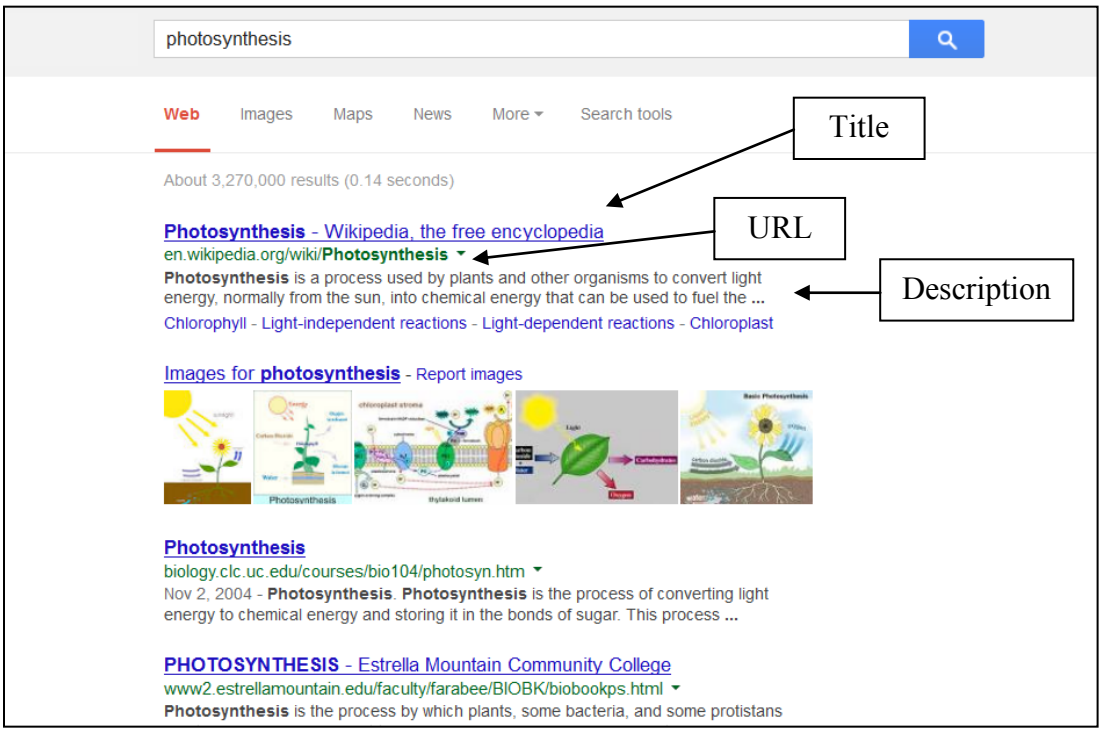
Table E1

Web Browser and Search Engine Used by Teachers During 30-min Search and Those Typically Used by Teachers

Teacher	Browser Used		Search Engine Used	
	30-min search	typically	30-min search	typically
A	Firefox	Safari	Google	Google
B	Firefox	Internet Explorer	Google	Google
C	Firefox	Google Chrome (had used Firefox in the Past)	Google	Google
D	Google Chrome	Google Chrome	Google	Google
E	Google Chrome	Work - PC (unspecified browser), Home - Safari	Google	Google
F	Google Chrome	(not specified)	Google	Google, VROOSH Dogpile
G	Google Chrome	Google Chrome, Safari, Firefox	Google	Google
H	Firefox	Internet Explorer	Google	Google
I	Firefox	Firefox at Work, Safari at Home	Google	Google
J	Firefox	Firefox	Google	Google
K	Internet Explorer	Internet Explorer	Google	Google

Appendix F

Sample Search Engine Results Page



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