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2. READING FOR EVIDENCE

INTRODUCTION

When we went to school our reading of information was quite different from that of students today. Information we had access to was limited in range and predominantly in print form and there was an implied perception of trust in the information due to the accountability that was attached to print forms. Today we live in a ‘digital universe’ where information is rapidly expanding; it is instantly and continually accessible without having to leave the confines of our classroom or home, and almost immediately available from the time of generation and often with little evidence of source or validity. The information varies from vitally important matters of life and death to the trivial and unimportant, such as what a distant relative ate for supper. The International Data Corporation (IDC) predicts that digital information will grow 47% in 2011 alone to reach 1.8ZB (1.8×10^{21} bytes) and rocketing to 7 ZB by 2015 (IDC, 2010). This enormity of information changes the landscape of how in our everyday lives we filter, select, and read information and how it is shared and used in classrooms. Of particular importance is how students themselves find and evaluate information—tasks that teachers have set for students for generations but now occurring in a rapidly changing digital universe.

Within the field of science, the terms ‘information’ and ‘evidence’ carry a meaning that goes beyond the general use of the terms, and thus in science teaching it is more appropriate to use the prefix ‘scientific’. Scientific information and evidence are integral parts of the nature of science itself with scientists relying on scientific information generated through the work of other scientists to lay the ground for new research questions, to substantiate methodology and verify results, and to keep up with new developments and new sources of research data. Indeed scientists spend around two to three months a year retrieving and reading scientific literature, in particular journal articles (King, Tenopir, & Clarke, 2006). However not any old piece of information will do; articles in Wikipedia for example are unlikely to be used to substantiate methodologies by a scientist planning new avenues in stem cell research due to its open source nature and unidentified authorship. The culture of science expects members to use peer-reviewed published work whether it be electronic or print scientific journals. The peer-review process provides a quality control that verifies research methodologies, results and conclusions, and the use of findings as evidence, which policy makers can then utilize to make decisions and form policies. Moreover, the digital universe has precipitated new ways for scientists to share and publish their research, in this case making their research even more accessible to laypeople (Bjork, 2007) with information often being frontier science where consensus has not yet been reached

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(Kolstø, 2001). When teaching science, teachers tend to model as much as possible the practices of science but the use of evidence in school science, whether in illustrative or investigative work, is sometimes quite different from evidence used in socio-scientific issues and scientific research (Levinson, 2006; Gott & Duggan, 1995). Current emphases in science curricula around the world are upon scientific inquiry, the nature of science, and scientific literacy. For the most part, peer reviewed articles generated through the process of science are inaccessible to high school students due to specialized vocabulary, although elsewhere in this book adapted primary literature is used to engage students (see Chapter 3). The inaccessibility of scientific literature to those outside the culture of science is a well-documented phenomena (Hayes, 1992) so, traditionally, information given to students to support their learning in science is provided by the teacher in the form of class notes or dedicated textbooks. Such textbooks are usually written by science teachers together with scientists and reviewed for accuracy by scientists and teachers. The textbooks are either school- or teacher-selected and provide the science students with everything they need to know to pass a certain grade in school. However, we now are at an interesting time in science education because students are growing up and living in a digital age, living their lives through technology where print books are rarely part of their lives outside of school. Utilizing habits of students' life worlds is an important strategy that teachers can adopt to motivate them in school. Yet, even when teachers try to make this possible, such as with technology, there are often obstacles that hamper inquiry-based learning, such as firewalls and filters put in place to protect young people (Farris-Berg, 2008).

Our research explored two aspects of information literacy skills of high school science students making judgments about the validity of the information they read, which we have named 'reading for evidence'. The term 'information literacy' refers to the set of skills required to identify information sources, access information, evaluate it, and use it effectively, efficiently, and ethically. In high school it is not unreasonable to suggest that teachers would expect most of their students to already have the basic reading and writing skills to participate in their lessons. Is the same true for information literacy? Just how information literate are high school science students and how do they develop those skills? What exactly do students do when we set them information seeking tasks? How might the outcomes impact on their understanding of science? What implications are there for the teaching of science? These are some of the questions that we have explored through our research and that we consider here. The questions are related to what we can do to improve scientific information literacy—reading for evidence.

UNESCO (2009) describes information literacy as follows:

> Information literacy enables people to interpret and make informed judgments as users of information sources, as well as to become producers of information in their own right. Information literate people are able to access information about their health, their environment and work, empowering them to make critical decisions about their lives, e.g. in taking more responsibility for their own health and education (UNESCO, 2009, para 2).

This is not entirely commensurate with the notion of scientific literacy that is currently a key focus of science curricula worldwide. “Scientific literacy is the knowledge and understanding of scientific concepts and processes required for personal decision making, participation in civic and cultural affairs, and economic productivity” (National Research Council, 1996, p. 22). Norris and Phillips (2003, p. 225) provide a more helpful detailed analysis of concepts of scientific literacy:

– Knowledge of the substantive content of science and the ability to distinguish science from non-science;
– Understanding science and its applications;
– Knowledge of what counts as science;
– Independence in learning science;
– Ability to think scientifically;
– Ability to use scientific knowledge in problem solving;
– Knowledge needed for intelligent participation in science-based issues;
– Understanding the nature of science, including its relationship with culture;
– Appreciation of and comfort with science, including its wonder and curiosity;
– Knowledge of the risks and benefits of science; and
– Ability to think critically about science and to deal with scientific expertise.

We also have a host of other types of literacy such as digital literacy, technology literacy, critical literacy, media literacy, etc., and whilst some have their own specific contexts and definitions there is also some redundancy of terms (Sensenbaugh, 1990). Yet they all share the goal of making sense of the ever expanding universe of information. Given that information literacy transcends curriculum areas, it is important to ensure that any skill development is contextualized within the discipline. This is particularly important in science where evaluating information is an integral part of the nature of science. A new literacy is thus emerging that addresses this concern and that is scientific information literacy. Our work presented here contributes to an understanding of what this form of literacy might look like in the classroom.

There is a some research already in this field and our review of the literature on finding information shows that science students are challenged by evaluating the veracity and objectivity of information (Adams, 1999), and that they demonstrate significant preference for the internet and electronic resources over print resources (Barranoik, 2001; Jones, 1999; Shenton, 2007). In addition most students demonstrate poor search skills (such as difficulty selecting search terms, appropriately citing sources) (e.g., Barranoik, 2001; Fidel, Davies, & Douglass, 1999; Scott & O’Sullivan, 2005). Moreover, when working with information on the internet, high school students are unable to distinguish credibility in websites, that is, demonstrate insufficient higher level thinking when credibility or accuracy is being assessed (Brem, Russell, & Weems, 2001). When they do find information deemed to be relevant, high school biology students’ read scientific documents superficially (Brill, Falk, & Yarden, 2004) with minimizing effort as a key driver of students’ information seeking (Jones, 1999). Students also seek the ‘right’ answer and tend to judge relevance on the basis of convenient access and superficial criteria (Heinström, 2006). A number of papers have also explored how students make judgements about the evidence in media reports of scientific research (e.g., Kolstø, 2001; Norris & Phillips, 1994; Phillips & Norris, 1999; Ratcliffe, 1999). These papers show that students learn significantly about the nature of science from considering such reports but the criteria they use are based more on the processes of science than on the facts or content knowledge. These are particularly important observations given that much information on the internet about scientific topics lacks this contextual information and explains why more superficial criteria are being used by students.

Our research took place in the province of Alberta, Canada. The Alberta curriculum clearly identifies the importance of information seeking skills both from the Focus on Inquiry curriculum document (Alberta Learning, 2004) as well as within subject areas. For example, in our study we worked with students studying Biology 20 which has the following goals: “Students will be encouraged to seek and apply evidence when evaluating alternative approaches to investigations, problems, and issues; e.g., question arguments in which evidence, explanations or positions do not reflect the diversity of perspectives that exist” (Alberta Education, 2007, p. 16). Again, these skills are consistent with standard information literacy skills. Further, the biology curriculum includes the following expectations for high school students’ experiences and learning:

– understand that scientific language is precise and specific terms may be used in each field of study;
– research, integrate and synthesize information from various print and electronic sources regarding a scientific question;
– apply given criteria for evaluating evidence and assess the authority, reliability, scientific accuracy and validity of sources of information;
– research, integrate and synthesize information from various print and electronic sources relevant to a practical question;
– research, integrate and synthesize information from various print and electronic sources relevant to a given question, problem or issue; and
– select information and gather evidence from appropriate sources and evaluate search strategies (Alberta Education, 2007, pp. 8–10).

Moreover, the Alberta curriculum supports development of information and communications technology (ICT) skills (Alberta Education, 2008), which are absolutely consistent with information literacy skills as understood more broadly. We thus see an interesting paradox where the Alberta high school curriculum emphasizes the need to develop information literacy skills that are integral to the process of science, yet in science subjects little emphasis is given to information literacy or connection to science inquiry and the nature of science.

Full details of the research methodology from our study can be found in Julien and Barker (2009). The context of the research was a class task on finding information on Biomes rooted in the Biology 20 program of studies. We asked students as part of this task to reflect on the information seeking task in addition to interviewing students about the process.

The two key areas that we want to explore in this chapter are the use of textbooks and the internet as sources of information for students. The research literature suggests that many students are motivated to choose strategies that ensure they can complete the task in the shortest possible amount of time. Indeed students in our study expressed similar views about not wanting to waste time, and as a result the internet was the favourite method for finding information, followed by class textbooks. We suspect that this is because it is easier to cut and paste digital information into an assignment, but no one admitted to this possibly because of plagiarism issues!

CLASS TEXTBOOKS

In Alberta, there is a heavy dependence on the use of textbooks in science classrooms. Textbooks used in schools are approved by the province on the basis of a match with outcomes described in the Program of Studies. Schools and teachers then select specific books from the list of approved textbooks; students usually have access to one textbook in a subject area. In the development of these authorized textbooks, content is reviewed for accuracy and appropriateness by scientists and teachers and these experts are listed at the front of the book. So here we have an interesting situation of information in the form of a textbook which already has had several stages of evaluation, validation, and approval before getting to the classroom.

In our study, a number of students expressed a desire to use the class textbook as the main source of information despite not finding it easy to use. These students were making a crude cost-benefit analysis based on the fact that they assume that all the material presented in the textbook is relevant so they don't need to evaluate it and sift through irrelevant material, which wastes time. Students told us that they had absolute confidence in everything in the textbook because their teachers and schools recommend it to them and they have faith in the teacher and in the school. Andy said, "Well I used it [a textbook] because I knew it would be reliable. If the school would give it to us and it not be reliable...then that would kind of be defeating a bunch of purposes." So this presents an interesting issue for science teachers. The evaluation is vicarious having assumed to have been done by teachers, the province, and experts who have reviewed the material for accuracy and relevancy. Whilst many students are not aware of the behind-the-scenes evaluation, they are basing their trust in the textbook on the trust they have in their teachers. Here is an example of students accepting knowledge without question because of unconditional trust in the textbook, in the teacher, or in both.

Teachers could ask their students: "Would a research scientist studying antibiotic resistance in bacteria use a school textbook as a source of information to plan their work and, if not, why not?" While this question might seem quite ridiculous and the answer obvious, it will facilitate a discussion about information literacy, the differences between information and evidence, the rapidly changing nature of scientific knowledge, thus the nature of science. Clearly the purpose for using the information is a key factor in determining the level of evaluation given.

A useful extension task would be to compare the peer-review process in the development of textbooks, where secondary information is reviewed for accuracy and appropriateness, with peer review in scientific research journals.

The future of textbooks in science classrooms is unclear. Farris-Berg, who reported for Project Tomorrow on the next generation in science education, indicated only one in five students saw a role for textbooks in future science classrooms (Farris-Berg, 2008). There is no doubt that the trend for using electronic textbooks instead of print will continue, but it is unclear whether there will be any radical change in how the information is reviewed and selected. In addition, how a textbook is used in science class is a pedagogy that is under-researched, despite its implications for our work. From our own observations of science classrooms we regularly see teachers ask students to read chapters silently or out loud in round-robin style without any consideration of the nature of the information. Neither of these strategies will help students better understand scientific concepts (Walker & Huber, 2002) or read for evidence. What is clear is that we need to get students to be critical of textbooks and print information irrespective of authorship and explore what we mean by scientific evidence. A useful activity is to compare old textbooks with new on a specific topic to demonstrate just how much (or little) scientific understanding has changed over the years.

INTERNET

Findings from the in-class task in which students had to find information on Biomes were generally consistent with previously published research. Overall, even though students were given access to a wide range of information sources, the internet was the most frequently used source for the students' research (59% of sources identified). Google™ was the most used search engine to access either specific sites, such as Wikipedia, or in general searching. The dominance of Google™ in students' responses was noticeable. Students regarded Google™ as being 'the' internet and used the two terms interchangeably. In addition, Google™ as a source of information was used indiscriminately for all sources of information for school and home (i.e., for academic and for personal information seeking) and great confidence was placed in the web sites that Google provided, with many students simply using the first site listed from the search. Chandra stated, "I just Googled it and then I compared between different pages to see how accurate it was and then I went with the one that showed up the most". The largest proportion of students' responses to why they turned to the internet most often (35%) focused on perceived relevance of information found (i.e., answers the task questions). Accuracy of information was identified by comparing multiple resources for consistency in information provided (42%). Students mostly looked at the first three sites from a Google™ search and, if the information in these three sites was comparable, then this gave the students a measure of validity. Carrie noted, "I usually just click the first one and read it, and then I'll click a couple more and if they all say kind of the same thing then I'll keep that, because you're getting it from multiple sources, so chances are it's real." Repeatedly, credibility was judged by noting that references were provided (48% of respondents). Relevance was assessed according to whether the information found answered the task question to be addressed, that is, by topical relevancy (41% of responses). Students reported skimming information for relevant key terms in order to assess relevancy.

Students in our study indicated that they preferred to use the internet because it is convenient and familiar, and that searching by key word is easy. As Natasha states, "Well, I'm – it's more reliable than going to the library and trying to find a book..., 'cause it takes less time." Robert noted, "Well it's much more convenient than, you know, you want to do something else with your time. If you get the information right here, you can finish the task quicker." Kendra stated that the internet is "a lot more easy to access whereas the library and the textbooks we have to go to the library." However, their searching skills are quite unsophisticated. In general, students search by pasting the assignment question or task directly into the search box. They scan the first three or four web sites that appear for matching key words, and the content of these top sites are compared for consistency. Interestingly, Wikipedia is used and liked by many of the students, although there was an uneasy tension as students commented that Wikipedia is often the first webpage listed from a Google™ search, but it is widely judged by them as not being a valid source of information. Jimmy said, "Wikipedia was just another place to compare because Wikipedia is an open source. And then so, being an open source it is not exactly always reliable." Head and Eisenberg (2009) also found that students like to go to Wikipedia first as this collaborative, community-based online encyclopaedia gave students the big picture and language contexts. Their students described Wikipedia as their "first go-to place" because Wikipedia entries offer a "preview" and provide "a simple narrative that gives you a grasp" and "can point you in the right direction," and "helps when I have no idea what to do" (Head & Eisenberg, 2009, p. 11).

The trustworthiness of information that students accessed was predominantly viewed in terms of the site or resource including domain name rather than by evaluation of the content. For example, university sites were mentioned as being accurate, with some students viewing university sites as reputable and reliable using information from these sites for school purposes. However, examples given of university sites were from the U.S. rather than local Alberta institutions. For example, Allison said, "I use the University of Berkeley site cause they're a generally trusted university name and you can assume that you can trust the research they've done." However domain names such as "angelfire.com" were considered by one student to suggest unreliability. Evaluating information on websites by examining domain name only is a risky practice; students need to be better equipped at evaluating content. If you draw comparisons with making judgments about the accuracy of information in a book based on the title of the book then the basis for making that judgment is more obviously flawed.

DEVELOPMENT OF INFORMATION LITERACY SKILLS IN SCIENCE

The largest proportion of participants stated that they learned how to select information for science classes by experience with non-science school projects

(38%), and through non-academic personal experience (29%). Friends and family were frequently mentioned as those from whom the students had learned their skills. Overall, when asked directly, students expressed confidence in their information-finding and evaluation skills. Eva stated, “I guess just basically from years of experience I can tell whether or not something is reliable or not reliable.” Robert said, “If Wikipedia’s not first, then I just go with the first site Google™ gives me.” This concurs with Head & Eisenberg (2009) who found that most students have developed strategies, techniques, and workarounds through trial and error and designed their own methods that sometimes, but not always, help them find content when searching for information.

Students reported that their primary search strategy is keyword searching. While this approach is useful for new vocabulary (e.g., “podcasting”), when there is no thesaurus, when searching is resulting in few hits, or when a known item is sought (e.g., specific author), there are significant limits to the value of keyword searches. The students in this study are unfamiliar with the benefits of searching by controlled vocabulary to improve comprehensiveness and precision. In addition, these students are apparently unaware of how search engines identify potentially relevant sources. Thus, the limitations of searching by Google™, and of searching with only one search engine, are not understood.

The school in the research study was a very multicultural school with a Mandarin language program. One student for whom English was not his first language and who was a recent immigrant to Canada could not easily articulate what he had done to find information but had used the internet using English key words rather than in his native Mandarin language.

Overall, the students revealed unsophisticated evaluation skills. Understanding of critical evaluation criteria such as authority, accuracy, objectivity, currency, and coverage, was not evident from the students’ comments. Not one student used language that was commensurate with the nature of science, for example, ‘evidence’, ‘reliability’, or ‘validity’.

STRATEGIES FOR TEACHERS TO HELP STUDENTS FIND INFORMATION

It is clear that despite the unambiguous curricular mandates to develop information literacy skills, actual skill levels in the students in the study were underdeveloped. The “Focus on Inquiry” document (Alberta Learning, 2004), which explicates sound information-searching skills, is clearly insufficient to ensure that students are developing these skills. Actual classroom practices and teachers’ understandings and attitudes were not explored in this study, so their relationship to the results reported here remain uncertain. It is possible that teachers believe that students already have these skills, or perhaps that they themselves lack sophisticated skills and are therefore unable to provide guidance to their students. One reason for the lack of emphasis is that information-seeking skills are not directly assessed in the provincial exams. So, even when such objectives are listed in the curriculum they are unlikely to be taken seriously by teachers. This observation was pointed out by an Alberta science teacher at a science council professional development workshop where this study was discussed. Such assessment-led teaching is not confined to Alberta and is a common phenomenon worldwide. In order for content or skills to be taken seriously they need to be assessed. However, we do believe that this is a missed opportunity, particularly for science teachers.

Science lends itself very well to discussions about the construction of knowledge, accuracy of information, and evidence the students may find on the internet. For example, the tentative nature of scientific knowledge is a critical issue to address when developing information-seeking skills in science. A student in our sample who used his “grandmother’s encyclopaedia” to find information for all school tasks and personal interests irrespective of the topic, had not considered why he might need to use more contemporary resources. The 11th edition of Encyclopaedia Britannica published in 1911 presents quite a different view of the world than we see today. The word ‘Biome’ (the topic of the students’ science task) is not even included, and older books contain many descriptions of biological phenomena which would today be considered incorrect, for example, in pre-1980 books, the structure of the cell membrane. In order to counter these concerns, teachers could present relevant scientific information from historical and contemporary resources to demonstrate how knowledge and understanding have changed and why recent resources have the potential to be more accurate. An excellent example of such a task is presented by Warren (2001) who uses scientific knowledge about scurvy from a number of periods in history. This role play requires several students each to act out the role of a medical doctor at a specific time in history. They have to make a diagnosis and prescribe treatment for scurvy based on the scientific information and evidence that would have been available to them at that particular time in history. The survival rate of their patients is clearly linked to the scientific information demonstrating that we need to use the most recent evidence we have available to us.

As students are unaware of how search engines work and the way in which websites are ordered it would help if teachers drew attention to this. Of concern is the dominance of Google™, which is revered as *the* way to find information without any question or concern about underlying marketing strategies and economics filtering information. A simple task would be to present a search to the class using two or more different search engines to demonstrate just how serendipitous (or not!) the process is and to provoke discussions about the activities of information brokers such as Google™. Google™ ranking is based on popularity as determined by internal links (so Wikipedia is highly ranked). Some sites pay to be indexed (and pay for ranking), for example, the right column list in Google™, and students need to be alerted to the impact of this on the information they obtain. Other points to alert students to are that every word is indexed and order matters. Ranking algorithms are secret but first lines, titles, metadata tags, top of page, linked words, number of links to page are part of the process. It is widely known that abuse and manipulation are possible and that the domain (geographic location) matters—and that there is censorship in some countries. Some other advice that could be provided to students for searching:

- Look for the name of the author or organization
- Go to the home page of the host site to find out about the organization
- Use a search engine to find more information about the author
- Check for date of last modification (on page or using browser's "Document Info" or "Properties")
- Use the URL as a clue to authority
- a ~ indicates a personal page
- note domains (edu, gov, com, net, org, etc.)

We also found that students become overwhelmed when faced with 3 million webpages from their search term. Most students were unaware of Boolean Operators named after George Boole a 19th Century Mathematician. The main Boolean operators are:

- AND, which finds only those pages with both terms;
- OR, which finds pages with any one or any combination of search terms;
- NOT, which finds articles that exclude one or more terms (see Cohen, 2011).

Finally a common misunderstanding is that searching occurs on live sites but this is not so: the searches are of indexes, so information can be dated.

We see that overall students gave less emphasis to the process of finding information than the end product of the search. Indeed, Barranoik (2001) too found that biology high school students showed that they were more concerned with the content than the process. In our study many students found it hard to recall precisely what they had done or why, despite specific questions addressing the process in their assignment. Rarely are such questions asked of students despite increasing evidence of the benefits of metacognition (Brem et al., 2001). The ultimate goal was for 'information to go', finding precise information in the easiest way possible and in the shortest amount of time. Thus, we recommend that teachers give more emphasis to the process of finding information by perhaps assigning marks for process as was done in the task set for this research.

Students' primary search strategy was through the use of natural language (keyword) searches and this strategy is particularly useful:

- for new vocabulary (e.g., "podcasting");
- when there is no thesaurus;
- when you're getting few hits; or
- when a known item is sought (e.g., specific author).

However, students should also be helped to go beyond keyword searching by using controlled vocabulary, which are subject terms used to identify records in a uniform manner. For example, in the ERIC database, "library instruction" is the official subject term used for “bibliographic instruction” and “library orientation.” The advantages of controlled vocabulary are:

- Facilitates gathering like items (brings together documents about similar concepts even if those concepts are identified by synonyms);
- Improves comprehensiveness of search (missing a critical synonym is less likely);
- Improves precision of search (e.g., search for “students, medical” will exclude all other students.
- Gives insight into ambiguous terminology: MERCURY (Roman mythology) vs. MERCURY (element);
- Broadens understanding of available terminology.

INFORMATION LITERACY AND SCIENCE INQUIRY

The connections between information literacy, scientific literacy, and science inquiry seem to be under-utilized and we argue that more attention to making these connections could help promote a better understanding of the nature of science. However an important point here is that finding, evaluating, and using information are critical parts of how a scientist conducts research inquiry. Thus, if school science inquiry models the practices of scientists, then emphasis on this part of the process could also enhance an understanding of the nature of science. Science inquiry is often misunderstood as being the same thing as the nature of science. Much of the confusion can be attributed to the variety of approaches advocated for science inquiry. For example, Crawford (2000) emphasized that teachers’ ideas and practice about inquiry are varied and complex. The starting point of inquiry is also ambiguous. For some teachers, a problem or question is given to students. With only a question or problem to go by, the students may begin science inquiry with sparse and disorganized background knowledge. Therefore, they should first conduct background library or internet research (Windschitl, 2008). Windschitl views such information-seeking tasks as being ‘supporting activities’ of inquiry, which help prepare students to participate more meaningfully in the core activities of inquiry by acquainting them with necessary concepts, ideas and skills (Windschitl, 2008). Whether the information seeking is seen as part of the inquiry process or supplementary to it, science classrooms where students follow an inquiry model of learning are ideal in which to develop and refine information literacy. In a science context, the parallels of information seeking with science inquiry could be to the benefit of teachers and students, each one having the potential to reinforce the other with the additional bonus of helping to understand the processes of science. The whole process of information seeking is remarkably similar to the stages of science inquiry, despite being considered by Windschitl (2008) to be a subset or complementary activity to science inquiry. Introducing information-seeking tasks in the context of the work of scientists may be a helpful strategy. For example, would scientists working in stem cell research use their grandmothers’ encyclopaedia to find information to help them plan a new experiment? This sort of question could lead to useful discussions about the nature of scientific knowledge.

Presenting the task as a scientific question or encouraging students to pose a question to answer is a good way to start. Teachers might consider using a constructivist approach, eliciting students' prior understanding about the topic. One of the possible ways in which information seeking may be related to science inquiry is presented in Table 2.1. Such a side-by-side comparison helps reinforce the processes of scientific inquiry in addition to information seeking. Alternatively highlighting the role of information seeking as a pre-cursor to scientific inquiry (Windschitl, 2008) would be equally as useful.

Table 2.1. Links Between Information Seeking and Scientific Inquiry

Information Seeking Task	*Science Inquiry*[a]
Goal: Finding credible information to meet an identified need	Goal: Developing defensible explanations of the way the natural world works
Elicit prior knowledge	Elicit prior knowledge and organize what we know and what we'd like to know.
Plan search strategy (identify key words, appropriate synonyms and combinations, identify possible credible sources)	Generate hypothesis
Execute search strategy (iteratively, according to results)	Seek evidence to support or refute the hypothesis
Evaluate information found according to standard criteria	Construct an argument
Communicate or present results as required	Communicate findings

[a]Partly adapted from Windschitl (2008).

Cultural Context

We also need to consider that evidence is constructed through a western world view of science. As we begin to recognize and value the role of traditional knowledge systems in our curriculum, we know that some cultures value the written word less than oral traditions. For such cultures, reading for evidence is likely to be an alien concept. What is more relevant is the notion of reading the environment that is considered in Chapter 5. Given the multicultural context of many of the world's classrooms, a useful strategy would be to encourage students to search for information in their first language rather than the language that is predominantly used in the classroom. This opportunity could be used to highlight any differences that may arise from searching in different languages, and to consider the significance this has for science. Searching in their first language may help students improve understanding in specific content areas and would give the students a break from the constant demands of having to translate everything. In addition, such an approach may enable inclusivity of parents or guardians in the students' school work.

Moreover a focus on written information is also restrictive with regard to inclusion of traditional knowledge and aboriginal world views where much of the information is visual or oral. As oral and visual traditions are integral to an understanding of traditional knowledge, it is useful to discuss similarities and differences in recording of knowledge and information between western world science and traditional world views. Indeed the Alaska Native Science Commission (ANSC, 1994) website provides such a comparison.

Textual Scientific Inquiry

The fact that students evaluate information superficially led us to develop a teaching prototype for use in secondary classrooms that facilitated a science inquiry approach on a piece of textual information. The rationale was to enhance students' understanding of science inquiry, to broaden the range of inquiry approaches that might be considered in the science classroom, and to develop more sophisticated scientific information literacy skills in students. Researchers such as Kolstø (2001), Ratcliffe, (1999) and Norris and Philips (2003), who have worked with young people dealing with media reports of science, have indicated that some of the criteria students use to make judgments about information are based on the ways in which the research was conducted and by whom. These criteria are more to do with the processes and nature of science than with the information *per se.* Levinson's (2006) work with teachers and controversial socio-scientific issues highlighted a need for: "facts; the reliability and validity of evidence; and the contrast between facts and values" (Levinson 2006, p. 247). We wanted to focus on the information itself and not necessarily on how it was constructed, so we focused on the distinction between scientific facts, misconceptions and values and how these are used to inform and educate students about a range of socio-scientific issues.

We initially provided students with some broad descriptions of what facts, misconceptions and values are. We indicated that factual statements attempt to describe. Thus, a fact is a verifiable statement of what is true. For example, the estimate of North Atlantic Harp Seal population in Canada in 2011 is 9 million based on population estimates. Another definition is that statements are facts if they "remain stable when challenged" (Bingle & Gaskell 1994, p. 197). Factual statements (which can be specific, general and even theoretical) attempt to describe, but not evaluate the worth of a thing or action. (Note that some theorists believe that scientific facts are not completely value free, but this refinement was not considered for the purposes of this study.) Also we encouraged students to think about the difference between a scientific fact that is verified by the scientific method, and descriptions which are a 'matter of fact' but are based on informal evidence such as a personal observation. We proposed to the students that a misconception (sometimes referred to as a myth) is sometimes treated exactly the same as fact because a myth is what people think is fact. How they arise is unclear but it may be based on incomplete evidence, partial truths, or being misled through advocacy groups or the media. Finally, we suggested that values are opinions about how things should be and place value (positive or negative) on the way things are (or were, or could be). Values cannot be proven right or wrong by scientific methods. An example of such a value is, Seals should not be hunted. We also encouraged students to recognize that scientists who have studied the issue, have scientific qualifications, and may even be described as 'expert', do not necessarily have values superior to anyone else. There are often no right or wrong answers to public issues and more often than not scientists will not make value statements when doing science because they are stepping outside the boundaries of science.

Our prototype teaching method used content analysis, which has a long history as a research method used to measure and analyze textual material. Content analysis is used in media studies to measure some aspect of the content of written, spoken or published communication by systematic, objective, and quantitative analysis. It is a means of trying to learn something about people or organizations by examining what they write. Neuendorf (2002) provides a helpful definition:

> Content analysis is a summarizing, quantitative analysis of messages that relies on the scientific method (including attention to objectivity, intersubjectivity, a priori design, reliability, validity, generalizability, replicability, and hypothesis testing) and is not limited as to the types of variables that may be measured or the context in which the messages are created or presented (p. 10).

It assumes that what is written reflects the behaviour and attitudes of the author or the organization. In our teaching prototype, we used it as a teaching tool rather like we use scientific method as a teaching tool in scientific inquiry. Essentially, it follows an inquiry model so the strategy has the potential to reinforce students' skills in scientific inquiry. Text or images are used as a source of data that can be measured using a series of parameters recorded in a table known as a coding frame. The parameters in the coding frame can be provided by the teacher or developed by the student depending on the type of inquiry approach being used. To differentiate between levels of textual inquiry we proposed a model based on Bell, Smetana, and Binns (2005). As can be seen from Table 2.2 and Table 2.3, the amount of information provided to students decreases as the inquiry level increases from level 1 to level 4.

The idea was to introduce the activity to students at a level matching their previous experience of science inquiry and ability and to provide progression through increasing sophistication of the technique. To familiarize students with the approach, we suggested starting with level 1 then moving through the levels as students gain confidence in the approach. The model can also be used as a differentiation tool in the classroom to provide different tasks for a range of abilities.

Table 2.2. Levels of Textual Inquiry

Inquiry Level	*Description*
1. Confirmation	Teachers present a question, a coding frame and results. Students interpret the results and make conclusions.
2. Structured Inquiry	Teachers present a question and a coding frame. Students collect data, interpret the results, and make conclusions.
3. Guided Inquiry	Teachers present a question. Students collect data using coding frames that they have developed. They interpret results and make conclusions.
4. Open Textual Inquiry	Students investigate questions that they have formulated. Students collect data using coding frames that they have developed. They interpret results and make their own conclusions.

Table 2.3. Information Given to Students in Textual Inquiry

Level of Inquiry	*Question*	*Coding frame*	*Data*
1	✓	✓	✓
2	✓	✓	
3	✓		
4			

Selecting Appropriate Materials

The first step was to collect some contrasting pieces of information that address a socio-scientific issue that was being explored in class. Two is the minimum number so that comparisons can be made. In our pilot studies some teachers used three pieces of information. As confirmation that teachers and students are swamped by too much information we found that this was one of the most difficult parts of the task. We encouraged teachers to use materials they had selected so that they would be relevant to the context of their schools and be appropriate for their students. We found that the majority just wanted to use materials we had provided. They could find lots of information but it was discerning the contrasting material that proved to be too big a challenge and too time consuming.

We thus provided three sources of information for two contexts (Edmonton Sun, 2006; Fink, 2007; Fisheries and Oceans Canada, 2006): the Seal Hunt and Climate Change. Considering the seal hunt case, we asked the students: How are scientific evidence and opinions/values used to promote or reject the seal hunt? The focus was to get students to think about the types of scientific evidence and facts used in the discussion of the issue and the range of value statements. To help them on their way we asked them to brainstorm both pro-hunt and anti-hunt reasons (See Table 2.4).

Table 2.4. Examples Provided by the Students

Pro-hunt	*Anti-hunt*
Too many seals	Cruel/inhumane
Provides jobs for people	Hunt is unsustainable and seal populations will fall
Food for local people	Most people don't want the hunt
To allow more cod	Seals don't eat much cod
Provides pelts for lucrative fur industry	Synthetic clothes are better
Provides penises for traditional herbal medicine	There's no scientific evidence in support

We then set the context by asking the students to think about types of scientific evidence that would support of refute these arguments: data on seal populations; data on cod population; research on pain and suffering by seals; and opinion surveys. We set three sequential tasks using content analysis. For the purposes of the pilot we provided coding frames (data tables) for them.

Task 1 Quantifying facts and opinions. We instructed the students as follows:

> You are provided with 3 different sources of information found on the internet on the Canadian Seal Hunt. The sample materials represent newspapers, Canadian government, and anti-hunt groups (International Fund for Animal Welfare, IFAW). With your knowledge of the seal hunt and knowledge of what facts and opinions are, do you think that there would be a difference in the number of facts and opinions in each of the different sources.
>
> Method- Examine each document and count the number of science facts and opinions in each. Choose a method which allows you to count facts and opinions separately. For example, underline the facts and circle the opinions or use coloured highlighter pens. You can use a coding frame such as the one below.

	Item 1 (Gov)	Item 2 (IFAW)	Item 3 (News)
Number of facts			
Number of opinions			

> Significance? What do your results show?
>
> Conclusion? Can you make any conclusions based on the data and small sample?
>
> Further studies? What would you need to do in order to confirm or refute your hypothesis?

This task clearly focused on differentiating between facts and opinions. There are some challenges with this approach given that 'facts' that inform socio-scientific issues can be drenched in values, highlighting that presenting such a dichotomy might distort students' understanding of the way in which evidence is generated and interpreted (Levinson, 2006). However, in our follow-up work with students, the task of differentiating between facts and opinions seemed to be incredibly satisfying leading us to believe that this is an important step upon which to build more discriminating and specific scientific information literacy skills. For example this grade 10 student still had naïve understandings of fact, opinions, and proof:

> The most useful activity is reading through 3 articles and deciding on whether the information is a fact or opinion. This helped me decide if there is proof or not. If there is a noted source, it was considered fact but if not was an opinion.

Task 2 Same story, different facts. For this task, students were instructed as follows:

> Now examine in the table how the scientific facts or evidence vary in the different documents.

Evidence	*Item 1 (Gov)*	*Item 2 (IFAW)*	*Item 3(News)*
Population data Harp Seals 2004	5.8 million	5.82 million	6 million
Number of Harp Seals killed 2005	No information	389,512	No information
Government quota 2006	No information	335,000	559,000
Value of seals 2005	$16.5 million	$51,710,145	$6 million
Pelt value	No information	$13 jacket pelt $22–55 beater pelt $7 adult pelt	$70
Population change	Triple population size of the 1970's	No evidence of rising population Currently stable	No information
Opinion polls	Ispos Reid 60% favour	Environics 69% opposed	No information

> Questions to consider:
>
> Do some of the facts vary across the three categories?
>
> If so, why might this be so?

Students found this exercise the most surprising. They learned that what might appear to be exact statistics (e.g., government quotas) could have different figures depending on the source. They also connected the activity with how they may present their own data in traditional labs in school and the importance of accuracy. One Grade 10 student said, "My labs will be more valid because I will be comparing my findings to more accurate data."

Task 3 Informal evidence. Students were guided as follows:

> Some of the articles may use what would be regarded as 'informal evidence', that is, considered as a common sense view of the issue or individual observations. These could not be counted as scientific evidence because they have not been tested or thoroughly investigated but have slightly more value than pure opinions because they are based on reality.

Evidence	*Item 1 (Gov)*	*Item 2 (IFAW)*	*Item 3(News)*
Helping cod stocks	No information	There is no evidence that culling harp seals will benefit commercial fisheries	No information
Population change	The harp seal population size is healthy and abundant	There is no scientific reason to cull Harp Seals	"Seals aren't out here" "Hunters hunt for scarce animals" "High mortality due to climate change"
Cruelty	The club or hakapik is an efficient tool designed to kill the animal quickly and humanely	Canada's commercial seal hunt is unacceptably cruel	"Several seals shot and left to die on the ice" "A number of pans …were empty and stained with blood"

We found from using the prototype in schools that students really enjoyed doing something active with the text rather than reading and discussing. They were motivated by highlighting, counting and entering data into a table or spreadsheet and they also enjoyed the fact that it was quick to do and they had something tangible to show for their consideration of the material. Reading and discussing does not leave students with any record of their analysis, leaving them feeling that nothing has been achieved. Most students were surprised that facts might be different in different sources particularly when they might have been previously deemed credible by using superficial criteria such as type of organization. They liked using web-based resources and working collaboratively on the tasks.

One of the greatest benefits commented on by virtually all of the students and teachers was that the activities enhanced an understanding of scientific inquiry.

> In all honesty, this exercise was the most useful as it forced us to critically analyze the truth in each and every sentence. We did something similar in English class and it really widens your eyes and makes you notice that not everything you read in an article is 100% true. We learned that it's much more difficult to prove opinions than facts. (Grade 10 student)

> The topic has greatly improved my understanding of scientific inquiry because it gave me clear information in sorting out if the statement is a fact, misconception, or opinion. It also made me understand that comparing issues with a few other articles is necessary for scientific inquiry to see if it's valid. (Grade 10 student)

> Before the topic I didn't know what scientific inquiry was but now I do. (Grade 10 student)

The teachers involved in the activities also recognized the contribution of the analysis to an understanding of scientific inquiry and thus reinforced an understanding of the nature of science. However they did not believe that an inquiry approach generally helped students score better in the provincial exams. Using the activity as an open-ended inquiry was too time-consuming for a classroom-based task, but teachers thought that it was a very helpful scaffold for developing critical thinking skills.

> I think it helped them understand science inquiry. I think it did for some of them. It makes them a little bit more thoughtful and makes them think a little bit more about what they are doing in science rather than just information overload. Especially on topics such as this that they are going to see again in social studies down the line and maybe further down the line. (Teacher Science 10)

So when reading for evidence, science students should be encouraged to read and count! Reading as a task is unlikely to develop critical thinking skills and a science inquiry approach using content analysis helps students really differentiate between facts, myths, and values and thus read for evidence. However, whilst it is helpful to highlight the distinction between facts and values what is more important is to focus on examining all sources of knowledge critically (Levinson, 2006).

CONCLUSION

It is perhaps inappropriate to expect teachers to deliver and interpret curriculum in areas where their own skills require significant development. The complex task of supporting the interpretation of evidence in controversial issues needs to be part of a teacher's repertoire. Yet, teachers give priority to day-to-day functions of teaching over reflection about the nature of evidence in controversial issues (Levinson, 2006). Indeed, Levinson goes on to cite Bartholomew, Osborne, and Ratcliffe (2002) who found that teachers, when teaching controversial issues in science perceive their primary function as dispenser of knowledge and provider of factual information (Levinson, 2006). Moreover, Williams and Coles (2007) interviewed teachers in the United Kingdom and found that teachers lack information literacy skills, especially searching and evaluation skills. Asselin (2005) found that a lack of time to teach information literacy is a significant barrier for teachers. We are at a curious point in time when many students have better ICT skills than their parents or teachers and this can be intimidating. There are some resources for teachers already. Some science resources, for example, Ebenezer and Lau (2003), fail to address the information literacy skills highlighted in this chapter including the necessity to explore the nature of scientific evidence when reading scientific information. Undoubtedly, information literacy needs to be explicitly addressed in the classroom. In scientific disciplines, scientific literacy and information literacy are inextricably linked. Teaching students skills in searching for and evaluating information within a science inquiry framework has the potential to help them understand better the nature of science and the nature of scientific knowledge. In addition, it will help them learn more widely applicable information literacy skills for use in daily life. The value of these skills is unchallenged, but significant challenges to inculcating them remain.

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