Creating an Engaging Science Inquiry Activity for Middle School Students That Incorporates Online Remote Access to Analytical Instrumentation

Nikki Stewart, Susan Lidster, Tory Anchikoski, Bruno Cinel, Sharon Brewer and Carol Rees

Introduction

The decline in young peoples' interest in science and technology education and the reduction in the proportion of students choosing to pursue careers in science and technology have been causing concern internationally for over a decade (OECD 2006). It is known that young people's attitudes to science and technology are usually established early in life and that efforts to encourage interest and build awareness are best targeted toward middle school students (DeWitt, Archer and Osborne 2014; Riegle-Crumb, Moore and Ramos-Wada 2010). This context prompted three initiatives that came together to create the learning opportunity for middle school students evaluated in the pilot study described in this paper. In the context of their inquiry project, the Grade 8 class worked with science professionals to remotely use an instrument in the university chemistry lab to analyze river water samples for total nitrogen. A pilot study of the initiative that examined students' responses to survey questions using the lens of *productive disciplinary engagement* (Engle and Conant 2002) indicated high levels of student engagement, specifically in the discipline of science, that were productive in advancing their learning of science and awareness of the actual practices that science professionals use. At the end of the paper, these findings are corroborated and expanded upon by the teacher in her reflections. Further work will look at how this productive disciplinary engagement develops, by analyzing video recordings of students, teachers and scientists interacting within this collaborative venture.

The Three Initiatives

1) **A Cross-Curricular Inquiry (CCI) Program for Grade 8 Students Cocreated by a Teacher/Principal Team in Response to the New British Columbia Curriculum**

Science education reform recommendations globally, including those in British Columbia, recommend shifting to a more inquiry- and project-based approach (British Columbia Ministry of Education 2012; Next Generation Science Standards 2013; Rocard et al 2007; Tytler 2007). In response to the new British Columbia K–12 curriculum, a teacher and principal at a southern interior British Columbia middle school cocreated a cross-curricular inquiry program (CCI) for Grade 8 students. Twenty-five self-selected students enrolled in the program and met from 8:30 AM to 3:00 PM every second day to engage in project-based learning that encompassed the curricular competencies of science, social studies and English language arts.

The class theme for the year, What Sustains Us, began with a study of water and the driving question: How can we create a potable water solution for an off-the-grid community? The class created a fictitious off-the-grid community, learned about the importance of and concerns surrounding access to clean drinking water, and researched different water treatment methods. Students also hypothesized the optimal location of the off-the-grid community along a local river. As Grade 8 students considered water treatment options, they began to question the optimal location for their off-the-grid community. Questions varied about topics such as water quality and the effects of geological and man-made features along the local river. Students also expressed an interest in testing water samples.

To increase engagement and real-world connections for students during their study of water, the school principal and classroom teacher approached faculty in the School of Education at a local university who were working on partnerships with faculty from multiple disciplines at the university in a network called the K-16 Research and Development Network.

2) **The K-16 Research and Development Network (K-16RDN) in Education Develops and Investigates Projects Linking School and University**

The K-16 Research and Development Network is a partnership between a university in British Columbia and a local school district. The K-16 initiative looks at education as a continuous journey from kindergarten all the way through to the completion of a degree. The initiative brings together teachers from the school district and faculty from various disciplines at the university to work on projects that introduce faculty expertise to K–12 classrooms. Faculty and teachers collaborated, planning projects together around the faculty members' disciplines. This provided an opportunity for secondary school students to deepen their understanding of what it means to study and work in the chosen discipline. Through these projects, students developed their skills in collaboration, creativity, innovation and communication. These are skills that benefited them in their learning in secondary school, in their transition to postsecondary education and in their success in the workplace.

The teacher and principal who cocreated the CCI program approached members of the K-16 Research and Development Network (K-16RDN), seeking partnerships with science faculty interested in the What Sustains Us project. A collaboration ensued with the chemistry faculty members who created the British Columbia-Integrated Laboratory Network (BC-ILN).

3) **The BC-Integrated Laboratory Network (BC-ILN) Has Been Providing Online Remote Access to Analytical Instrumentation in University Chemistry Labs for the Past 10 Years**

The BC-ILN is a project that provides online remote access to cyber-enabled scientific analytical instrumentation, instructional materials and expertise to enhance student opportunities in science education. Students that access remote instruments for chemical analysis manipulate and control real laboratory equipment and generate data from real samples; however, these students are physically separated from the lab and control the equipment over the Internet (Erasmus, Brewer and Cinel 2015; Kennepohl et al 2005; Ma and Nickerson 2006; Crippin, Archambault and Kern 2013).

Bringing the Three Initiatives Together

This collaboration between the CCI, K-16RDN and the BC-ILN involved creating a new, interactive, multiday student learning activity called Measuring the Total Nitrogen Content of River Water Samples (see Table 1), using educational resources previously developed by the BC-ILN (www.bciln.ca). Given the CCI focus and interest in water, a previously developed BC-ILN activity, Water's the Matter?! (Candow 2013), in which users determine total nitrogen (TN) levels present in water samples from select sites around a lake, was modified to a river scenario in consultation with the classroom teacher. New instructional materials including videos, an interactive poster and analysis instructions were created.

Table 1 below summarizes the three-day student learning activity, Measuring the Total Nitrogen Content of River Water Samples.

Accessing the Analytical Instrument Remotely

The instrument used to analyze water samples was a Shimadzu TOC-V/TN Analyzer controlled by a computer connected to the Internet. This modified activity aligned with the students' interest in determining, as a part of their project, the best location to situate a community along a river to ensure potable water. It augmented other work that students were doing on water quality. The sample sites created along the fictional river were chosen to consist of locations the students and their teacher had identified as potentially influencing water quality.

Samples corresponding to water obtained from the different locations on the fictional river were placed in vials and loaded into the instrument's autosampler at assigned positions. The software program Teamviewer (www.teamviewer.com) was then used to allow the students to remotely connect to the TN analyzer's computer and operate the instrument from a laptop

Day 1:	Introduction to Nitrogen and Its Potential Impact on Water Quality (1 hour)	
	Students watched a video about nitrogen, explored websites to answer questions about nitrogen and its effects on plant and animal life, participated in a nitrogen cycle game, and learned about some local research on the biological effects of algae blooms on amphibians.	
Day 2:	Introduction to Total Nitrogen, Instrumentation, and Fictitious River (1 hour)	
	1. Students were divided into groups of three, with each group representing a location along the river: wastewater treatment plant, small farm, campground, big farm, construction site, creek and middle of the river. 2. Students were introduced to the definition of total nitrogen. 3. Students watched the video *BC-ILN: How to Perform a Sample Analysis for Total Nitrogen*[1] and interacted with the university's chemistry lab through the touch screen tablet. 4. Groups used the interactive map[2] highlighting the seven points along the fictitious river and additional websites to research the potential effects of each location on nitrogen levels. 5. Groups used their research to rank the locations from highest predicted TN level to lowest predicted TN level. All groups recorded their predictions on a poster.	
Day 3:	Testing Total Nitrogen, Collecting, and Interpreting Data (2 hours) Working in the same groups as day 2, students visited six stations.	
	Station 1	Groups used the BC-ILN to test their water sample and record TN results.
	Station 2	Groups added the results of their TN test to a large bar graph.
	Station 3	Students watched BC-ILN- A video tour of the Total Nitrogen (TN) Analyzer[3] and answered questions about the TOC-V instrument.
	Station 4	As data was recorded, groups changed their predictions from day 1.
	Station 5	Using Google Maps and their own knowledge of the rivers, students located an area along the river similar to theirs and labelled it on a large map.
	Station 6	Groups coloured clipart images to represent their part of the river on the bar graph and on the map of the rivers.

Table 1. *Summary of the Three-Day Student Learning Activity: Measuring the Total Nitrogen Content of River Water Samples*

---

[1] https://www.youtube.com/watch?v=TVZoFI0vpHE (accessed September 12, 2017)

[2] http://edu.glogster.com/glog/bc-iln-activity-waters-the-matter-investigate-river-water-qual/2l3n0tk9xrv (accessed September 12, 2017)

[3] http://edu.glogster.com/glog/bc-iln-activity-waters-the-matter-investigate-river-water-qual/2l3n0tk9xrv (accessed September 12, 2017)

at their school. In addition, students could also view the interior of the instrument's autosampler carousel from the laptop via a Microsoft LifeCam VX-1000 (which was mounted in the instrument). In the university laboratory, a ceiling-mounted Canon VB-C50iR network camera allowed students to view both the instrument and laboratory using a touch screen tablet. Students could control the ceiling-mounted camera via the tablet to view and zoom in on any particular part of the instrument at will. Audio and visual communication between the students and a faculty member at the university was facilitated with Skype (www.skype.com).

When performing the water sample analysis part of the activity, students in groups of three would input their sample name using the instrument software, select the autosampler position for their sample and start the analysis. They would then observe the acquisition of data from their chosen sample in real time via the remote connection to the instrument computer, as well as hear and see the instrument in action using the cameras and microphone. Throughout the remote analysis and data acquisition, the students could interact directly with an instructor present with them or with the instrument technician at the university via Skype. At the end of the analysis, the TN level present in the water sample was determined and students recorded their results on a class graph that combined the class data obtained from all groups.

The Pilot Study

Theoretical Framework

This study focuses on engagement according to Engle and Conant's (2002) definition of *productive disciplinary engagement*. According to this definition, *engagement* includes general engagement (*engagement*), relevance to the discipline (*disciplinary engagement*), and the development of understanding (*productive disciplinary engagement*). Although Engle and Conant (2002) were using this definition in their study of classroom discourse, in this study it is applied to the analysis of students' responses to survey questions. The reason that this definition was chosen is that the researchers were interested not only in *engagement* in the BC-ILN experience, but also in how this experience led to *engagement in the discipline* of science and the *productive* learning of students. The pilot study survey questions have the capacity to show evidence of the students' engagement through the expression of their level of enjoyment, their level of interest in the disciplinary knowledge or their view of the extent of their learning.

Research Question

Based upon the definition above, the research question that we addressed in relation to the collaborative activity Measuring the Total Nitrogen Content of River Water Samples is, How would we characterize student engagement in the collaborative activity Measuring the Total Nitrogen Content of River Water Samples?

Methods

All 25 Grade 8 students in the class were invited to participate in the pilot study following procedures approved by the university ethics board for research involving human participants, and by the school district. Eighteen students and their parents or guardians agreed to participate by completing the survey on day three, after completion of the activity.

This survey instrument was developed from surveys previously reported in the literature that evaluated student engagement (Carle, Jaffe and Miller 2009; Ouimet and Smallwood 2005) and learning chemistry (Barbera et al 2008), together with studies that specifically focused on science laboratories (Domin 1999; Corter et al 2011). The survey instrument had 14 questions total: 13 four-level Likert scale questions and one open-ended question to allow students to comment on any aspect of the remote analysis experience. Using the productive disciplinary engagement framework outlined in the "Theoretical Framework" section above, the 13 Likert scale questions (Table 2) were characterized as follows: those that focus on engagement in general (questions 4 and 5), those that focus on disciplinary engagement (questions 1, 2, 3, 6, 7, 10, 12 and 13), and those that focus on productive disciplinary engagement (questions 8, 9 and 11). This productive disciplinary engagement framework was also used to categorize the students' responses to the open-ended question (Table 3).

	Likert category response frequency				Theoretical classification		
Question	Not Very Enjoyable	Somewhat Enjoyable	Enjoyable	Very Enjoyable	Engaging	Discipline	Productive
1. Overall, how enjoyable was the TRU online laboratory activity?	0	3	7	7	X	X	
2. How enjoyable was it working with real samples?	0	2	5	10	X	X	
3. How enjoyable was it using the instrument to do chemical analysis?	0	4	2	11	X	X	
4. How enjoyable was it communicating by Skype with TRU?	1	4	4	8	X		
5. How enjoyable was it controlling the camera?	1	1	5	10	X		
6. How enjoyable was it controlling the instrument?	0	1	6	10	X	X	
	Never/ Rarely	Sometimes	Often	Very Often			
7. How often were you actively participating in the TRU online laboratory activity?	1	5	5	6	X	X	
	Very Little	Some	Quite a Bit	Very Much			
8. To what extent did the TRU online laboratory activity help you understand chemistry concepts?	1	5	7	4	X	X	X
9. To what extent did you understand the learning objectives of TRU online laboratory activity?	1	3	9	4	X	X	X
10. To what extent did the TRU online laboratory activity make you want to continue on in science?	3	1	4	9	X	X	
11. To what extent did the TRU online laboratory activity provide you with an understanding of what it is like to do real science?	0	1	8	8	X	X	X
	Not Very Relevant	Somewhat Relevant	Quite Relevant	Very Relevant			
12. How relevant was the TRU online laboratory activity?	0	3	5	9	X	X	
	Not Very Engaging	Somewhat Engaging	Quite Engaging	Very Engaging			
13. How engaging was the TRU online laboratory activity?	1	3	5	8	X	X	
n=17							

Table 2. Pilot Study Survey Questions, Responses and Theoretical Classification

Results

The responses to the Likert scale questions and the open-ended question indicated that the majority of students who responded found high levels of engagement in the online laboratory. In Table 2, questions 4 and 5 focus on general engagement or enjoyment that is not disciplinary. Responses to question 4 indicate that 12 of 17 students found it enjoyable or very enjoyable to communicate by Skype, and 15 of 17 found controlling the camera enjoyable. These responses indicate that most students found engaging with the technology to be enjoyable. This finding is corroborated by the first response to the open-ended pilot study survey question, "It was fun, I liked controlling the camera" (Table 3).

Responses to Likert scale questions 1, 2, 3, 6, 7, 10, 12, and 13 (Table 2) and open-ended question responses 4, 6, 7 and 8 (Table 3) demonstrate students' disciplinary engagement (engagement in the discipline of science). Questions 1 and 13 are very

Open-ended question: Any comments you would like to make on your experience using the instrument over the web to do the TRU online laboratory activity?			
Responses	**Theoretical classification**		
	Engaging	Disciplinary	Productive
1. It was fun, I liked controlling the camera. But only 1 person got to sit at the computer and control what was happening.	X		
2. I think this hands-on learning activity is an excellent way to learn new concepts and to spark interest in science in young individuals.	X	X	X
3. Thank you so much for coming in to our class and showing us how nitrogen samples are tested.	X	X	X
4. I loved getting to have access to a new and accurate resource.	X	X	
5. :)	X		
6. I have always wanted to do stuff like this and now I have!	X	X	
7. It was very cool for them to come down to [our school] to do science with us.	X	X	
8. It was interesting to see how the instrument worked.	X	X	

Table 3. Pilot Survey Open-Ended Question, Responses and Theoretical Classification

similar, and responses demonstrate high levels of disciplinary engagement in that it was specifically the laboratory activity that 14 of 17 students (question 1) and 13 of 17 students (question 13) found enjoyable or engaging. Questions 3 and 6 are also similar—both refer to enjoyment level of using the instrument; question 3 refers to using the instrument to do chemical analysis, while question 6 refers to controlling the instrument. Results indicate that 13 of 17 students enjoyed using the instrument to do chemical analysis and 16 of 17 students enjoyed controlling the instrument. Additionally, two of the responses to the open-ended question reflect students' enjoyment of access to the science resources including the instrument (response four, "I loved getting to have access to a new and accurate resource," and response eight, "It was interesting to see how the instrument worked").

Responses to question 2 indicate that 15 of 17 students found it enjoyable to work with real samples. Interestingly, 14 of 17 students found the laboratory activity relevant (question 12). One interpretation of "relevance" in question 12 could be relevance to real life. These two sets of responses could also indicate that students' enjoyment is enhanced by real-life examples. This could further relate to question 7, indicating excitement that real scientists had visited the school.

Question 7 elicited findings that could be useful in future iterations of the project. Interestingly, only 11 of 17 students indicated that they were actively participating in the online laboratory activity. One possible explanation is that the students were placed in groups of three and there was one laptop (to control the instrument) and one tablet (to control the camera). Therefore, at any one time, only two students had hands-on control of the instrument or camera; therefore, one of the group members could have felt that they had not participated directly in the project. In the responses to question 10, 13 of 17 students indicated that the laboratory activity encouraged them to continue in science.

Questions 8 and 9 are similar in that they ask students about how the online laboratory activity affected their learning (productive disciplinary engagement). Question 8 refers to their learning of chemistry concepts, and question 9 refers to the learning objectives of the activity. Findings (Table 2) show that 11 of 17 students indicated that the online laboratory activity helped them understand laboratory concepts, and 13 of 17 indicated that they understood the objectives of the online laboratory activity. This was further supported by two of the responses to the open-ended question:

- "I think this hands-on learning activity is an excellent way to learn new concepts and to spark interest in science in young individuals" (response two)
- "Thank you so much for coming in to our class and showing us how nitrogen sample are tested") (response three)

Since the chemical concepts and learning objectives refer to measuring the amount of nitrogen in water, it is interesting to note that not all students indicated that the activity helped them with learning the objectives. Students were learning about the importance of nitrogen in water in other ways, such as online information searches of text and video. This result could indicate that some students found these ways of learning more useful than interacting with the instrument. Fascinatingly, responses to question 11 indicate that 16 of 17 students found that the online laboratory activity helped them to understand what it is like to do real science. This supports the overall initiative of the collaborating teams (CCI, K-16RDN, and BC-ILN).

Teacher Reflection

The classroom teacher made several key observations that supported our preliminary results. Anecdotally, the teacher noted increased levels of engagement of particular students during the project. The teacher reported that students who typically engaged in class activities were equally engaged in the online remote access experience. More notable were the increased engagement levels of students who typically struggled with traditional class work. The teacher recalled that during a 20-minute recess break, some students stayed in the class and "played" with the touch screen camera control and engaged in conversations with the laboratory technician at the university via Skype.

Following the activities on day 3, the classroom teacher asked students to answer additional informal feedback questions. Students used Chromebooks to submit their answers to the questions, What did you like about using the remote lab? What did you not like about using the remote lab? and What did you find interesting/surprising about the experience? Students were asked to answer candidly and were assured their feedback was not for marks. Every student participated in the feedback, and the teacher received 59 electronic, full-sentence responses. This is in stark contrast to the 8 handwritten responses to the open-ended question collected in the pilot project. The high participation rate for the teacher activity may be explained by the students' belief that teacher-assigned work must be completed to specific standards; however, other explanations may be the use of technology to collect information, or that students did not put as much effort into the pilot study survey because it was assigned immediately after the teacher-assigned questions. The questions asked in this informal feedback were not part of the ethics approval for this study; however, we will consider asking similar questions in future studies and use electronic collection methods.

Answers to these questions reflected themes similar to those found in the pilot study survey. Students demonstrated productive disciplinary engagement when they reported their learning about nitrogen in water. This is indicated in comments such as they liked "real accurate information that we didn't just find on the internet" and "how we got to see the total nitrogen in the samples." Several reported surprise at the results of the lab. One student commented that "there was more nitrogen in the river water near a small farm than the river water near a big farm," and even more students commented on how amazing it was to control the instrument remotely and watch the results in real time.

The teacher questions also revealed that some students felt left out during the water test, and enjoyment of the activity was reduced for some students who did not actively operate the remote equipment. These responses may partly explain the results of question 7 (Table 2) in the pilot study survey. We might infer that students' interpretation of *actively participating* means hands-on participation; consequently, a group of three students at a station with only two pieces of equipment could result in one-third of all students feeling less engaged.

The new British Columbia curriculum states that "The integration of areas of learning and technology also have opened the door for teachers and schools to approach the use of time and space in creative ways …" (British Columbia Ministry of Education 2012). It should be noted that the classroom teacher was not a science specialist. For this reason, the teacher sought out creative partnerships that would open doors to rich learning experiences for students in the program. Collaboration with the university to create this experience for students extended beyond using the Integrated Laboratory Network: faculty worked alongside the classroom teacher to intentionally support the students' existing study of water, and to create tools—like the interactive poster—that were accessible to all members of the class. The classroom teacher advocated for the students' needs, and faculty adapted their existing resources to suit the new audience. The result was a three-day student learning activity tailored to the class and their ongoing research. Overall, the classroom teacher was pleased with the learning and levels of engagement for students and is keen to do a similar project in future years.

Conclusions

Applying the theoretical framework of productive disciplinary engagement to the results of the survey was useful in that it allowed us to categorize student responses. From this, we were able to see that through the activity students were highly engaged in the discipline of science and that this engagement was productive in advancing the students' learning.

Limitations of the study were that (a) this was a pilot study with a small number of students in only one classroom; (b) the pilot study survey questions ask only about level of enjoyment in specific aspects of the activity, so it is difficult to know precisely what students found engaging; and (c) the study focused on students' impressions of their engagement and learning rather than direct observation.

Further research could include (a) more participants and classroom groups, (b) student interviews to allow expansion of feedback and (c) direct observation using video recording and analysis of the activity. Providing online hands-on access to scientific instrumentation for curriculum-appropriate investigations could be an effective and economical way to engage students in remote and rural communities. This pilot study indicates the power of the approach to support students' engagement and learning in the discipline of science.

References

Barbera, J, W K Adams, C E Wieman and K K Perkins. 2008. “Modifying and Validating the Colorado Learning Attitudes About Science Survey for Use in Chemistry.” *Journal of Chemical Education* 85, no 10: 1435–39.

British Columbia Ministry of Education. 2012. *BC’s New Curriculum*. Available at https://curriculum.gov.bc.ca (accessed September 12, 2017).

Candow, H, B Cinel and S E Brewer. 2013., “Activity 2: Water’s the Matter?!” BC-ILN Analytical Lab Development Through Undergraduate Chemical Education Research. Available at http://bcilntru.wixsite.com/water-quality/page3 (accessed September 12, 2017).

Carle, A C, D Jaffe and D Miller. 2009. “Engaging College Science Students and Changing Academic Achievement with Technology: A Quasi-Experimental Preliminary Investigation.” *Computers and Education* 52, no 2: 376–80.

Corter, J E, S K Esche, C Chassapis, J Ma and J V Nickerson. 2011. “Process and Learning Outcomes from Remotely-Operated, Simulated and Hands-On Student Laboratories.” *Computers and Education* 57, no 3: 2054–67.

Crippin, K J, L M Archambault and C L Kern. 2013. “The Nature of Laboratory Learning Experiences in Secondary Science Online.” *Research in Science Education* 43, no 3: 1029–50.

DeWitt, J, L Archer and J Osborne. 2014. “Science-Related Aspirations Across the Primary–Secondary Divide: Evidence from Two Surveys in England.” *International Journal of Science Education* 36, no 10: 1609–29.

Domin, D S. 1999. “A Content Analysis of General Chemistry Laboratory Manuals for Evidence of Higher-Order Cognitive Tasks.” *Journal of Chemical Education* 76, no 1: 109–11.

Engle, R A, and F R Conant. 2002. “Guiding Principles for Fostering Productive Disciplinary Engagement: Explaining an Emergent Argument in a Community of Learners Classroom.” *Cognition and Instruction* 20, no 4: 399–483.

Erasmus, D J, S E Brewer and B Cinel. 2015. “Assessing the Engagement, Learning, and Overall Experience of Students Operating an Atomic Absorption Spectrophotometer with Remote Access Technology.” *Biochemistry and Molecular Biology Education* 43, no 1: 6–12.

Kennepohl, D, J Baran, M Connors, K Quigley and R Currie. 2005. “Remote Access to Instrumental Analysis for Distance Education in Science.” *International Review of Research in Open and Distance Learning* 6, no 3: 1–14.

Ma, J, and J V Nickerson. 2006. “Hands-On, Simulated, and Remote Laboratories: A Comparative Literature Review.” *ACM Computing Surveys* 38, no 3: 1–24.

Next Generation Science Standards. 2013. Appendix F—“Science and Engineering Practices.” Available at www.nextgenscience.org/sites/default/files/Appendix%20F%20%20Science%20and%20Engineering%20Practices%20in%20the%20NGSS%20-%20FINAL%20060513.pdf or http://tinyurl.com/gkwltad (accessed September 13, 2017).

OECD (Organisation for Economic Cooperation and Development). 2006. *Evolution of Student Interest in Science and Technology Studies: Policy Report*. Available at www.oecd.org/science/sci-tech/36645825.pdf (accessed September 13, 2017).

Ouimet, J A. and R A Smallwood. 2005. “CLASSE – The Class-Level Survey of Student Engagement.” *Assessment Update* 17, no 6: 13–15.

Riegle-Crumb, C, C Moore, and A Ramos-Wada. 2010. “Who Wants to Have a Career in Science or Math? Exploring Adolescents’ Future Aspirations by Gender and Race/Ethnicity.” *Science Education* 95, no 3: 458–76.

Rocard, M, P Csermely, D Jorde, D Lenzen, H Walberg-Henriksson and V Hemmo. 2007. *Science Education Now: A Renewed Pedagogy for the Future of Europe*. Available at http://ec.europa.eu/research/science-society/document_library/pdf_06/report-rocard-on-science-education_en.pdf or http://tinyurl.com/2mjrd7 (accessed September 13, 2017).

Tytler, R. 2007. *Re-Imagining Science Education: Engaging Students in Science for Australia’s Future*. Melbourne, Australia: Australian Council for Education Research (ACER). Available at http://research.acer.edu.au/aer/3/ (accessed September 13, 2017).

Promoting Scientific Literacy Through the Use of Adapted Primary Literature in Secondary Science

Hyacinth Schaeffer and Bonnie Shapiro

The Need for New Approaches

In this article we present a discussion designed to help educators consider the value of a strategy to enhance secondary students’ science knowledge and a teaching approach that introduces students to primary scientific research. The article is based on research recently conducted during a professional development program designed to introduce secondary science teachers to a new teaching strategy that involved the introduction of adapted primary literature (APL) as a teaching tool (Schaeffer 2016). We introduce the article by first reviewing current thinking about the meaning and importance of developing scientific literacy in secondary classrooms, then present an argument for the consideration of APL as a potentially valuable approach.

Like many science programs worldwide, secondary science programs of study in Alberta are “guided by the vision that all students have the opportunity to develop scientific literacy” (Alberta Education 2005, 1). The programs further describe the knowledge, skills, and attributes that students must develop in order to attain a level of scientific literacy that is personally and socially relevant. Although the term *scientific literacy* is a commonly used term in STEM (science, technology, engineering and mathematics) education, it is useful to acknowledge that developing scientific literacy involves complex thinking skills that must be explicitly taught and practised by both teachers and students. Above all, a common understanding of what scientific literacy entails is essential. Cavagnetto (2010) explains that

> Scientific literacy is the ability to accurately and effectively interpret and construct science-based ideas in the popular media and everyday contexts. As such, scientific literacy is realized by an understanding of scientific principles, processes, and argument, all of which are supported by cognitive and metacognitive processes as well as critical reasoning and communication skills … [it] requires the abilities and background understandings to interpret meaning from text, talk and other modes of representations to build new interpretations. (pp 352–53)

This definition implies that simply knowing facts and being able to work through a set of predetermined processes are not enough to be considered a scientifically literate citizen. It further suggests that students must also be able to actively engage in examining and discussing the claims offered by the scientific community, particularly those they encounter in their studies. When students are encouraged to analyze and defend or refute their own and others’ interpretations, they are engaging in critical thinking and argumentation, both important attributes in the development of scientific literacy.

Gunn, Grigg and Pomahac (2008) refer to critical thinking as the “intellectually disciplined process of actively and skillfully conceptualizing, applying, analyzing, synthesizing, and/or evaluating information gathered from, or generated by, observation, experience, reflection, reasoning, or communication” (p 168). Additionally, researchers suggest that the ability to engage in scientific argumentation, or the use of evidence to support claims, is central to negotiating meaning and advancing knowledge, not only in science but also across disciplines (Hand et al 2009; Cavagnetto 2010). Analyzing the ways in which scientists develop and support their arguments offers students an authentic view of the processes of science and represents