Summary Comments, Deliberations, and Future Possibilities (Working title)

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Abstract

[This abstract will be completed later.]

In this final article, we briefly review and synthesise the central concerns in science and language research and practice that arose from the deliberations at an international conference, referred to as the first island conference. These central issues – (i) the definition of science literacy, (ii) the models of learning, discourse, reading and writing and their underlying pedagogical assumptions, (iii) the roles of discourse in doing, teaching and learning science, and (iv) the demands on teacher education and professional development in the current reforms in language and science education – provided points of departure for discussion of four possible new considerations to research in this field of endeavour that could contribute to a broader and productive scholarship and deeper and enriched understanding of both teaching and learning. These considerations, each from well established fields of literature, are the need to develop support for a contemporary view of science literacy, the role of metacognition in science learning generally, the role of multiple representations in knowledge building and science literacy, and the need for more focused teacher education and professional development programs. We synthesise the conference deliberations and discussion of these possibilities to the field and also offer our views as to how such contributions can take place.(204 words)

Introduction

The first 'Island Conference' was designed to assess agreement and to promote convergence among diverse perspectives represented in the cognitive science views of language and science education research. The unwieldy title of the conference—*Ontological, Epistemological, Linguistic, and Pedagogical*

Considerations of Language and Science Literacy: Empowering Research and Informing Instruction—was maintained to remind participants of this goal. The title indicates a basic characteristic of scholarship in the role of language in science, science teaching, and science learning: diversity. This diversity starts with the expanded boundaries of discourse to include oral, written, symbolic, and physical modes of scientific language. Furthermore, this research community comprises multiple subcultures interested in sociopolitical, sociolinguistic, sociocultural, and sociocognitive aspects of language in doing science, teaching and learning science, and debating of science, technology, society, and environment (STSE) issues. The range of inquiry approaches—experimental, quasi-experimental, phenomenological, ethnographic, and other naturalistic methods—further diversifies the research community. Duschl (2005) stated that there is:

> [A] need to locate language and discourse somewhere along … a continuum. At one end of the continuum are the strictly psychological explanations and biological cognitive mechanisms that help us understand the individual as a thinker. Here, language and discourse are perceived as a window into the mind. At the other end are the strictly anthropological explanations and cultural mechanisms that help us understand the individual in society. Here, language and discourse are perceived as tools for achieving, among other things, cultural capital and the construction, representation and dissemination of knowledge claims. (p. x)

He continued with a challenge to the science education and language education research communities by asking if the domain needed more work in developing a theoretical framework or in developing more effective classroom applications. The results from the first Island Conference to this challenge was—Yes! The final deliberation sessions of the Island Conference attempted to articulate critical questions for future research and pressing issues for teacher education, professional development, and evidence-based classroom practice. The increased popularity of language in science—some popular elementary and middle school inquiry science programs (Full Options Science System, Science and Technology for Children, etc.) and requirement by states such as Florida for science materials now include or require language considerations in science—is of mixed benefits because of the ways in which these materials are used in classrooms. An informal survey of language in science teaching articles in teacher journals (*Instructor, Reading Teacher, Science*

Teacher, Science and Children, Science Scope, Science Activities, and others) indicates numerous suggested applications for classroom practice with little or no theoretical or evidential base to justify their claims. Most of these professional articles are based on ‘craft’ experience and personal opinions. The central issues of concern in science and language research and practice are the definition of science literacy, the models of learning, discourse, reading and writing and their underlying pedagogical assumptions; the roles of discourse in doing, teaching and learning science; and the demands on teacher education and professional development in the current reforms in language and science education.

Background

Fensham (2004) provided a historical review of the ideas of science literacy and the evolutionary changes that have moved ‘Science Literacy for All’ toward its current conception. His descriptions of the development of a ‘science for citizenship’ curriculum provided a fresh perspective on what science literacy for all might include and not include. However, in our view, the examples and the proposed curricular emphases involving personal well-being, democratic well-being, socio-economic well-being and scientific well-being do not place sufficient emphases on students' cognitive tools and communication abilities so that they are able to maintain and renew their science literacy after leaving the formal education system. Any promotion of science literacy should empower people to be literate in the discourses of science.

Science Literacy

Science for citizenship and science literacy are still not without problems, but Norris and Phillips (2003) provided an interpretation that allows its application to the mandatory levels of the K-12 schooling and beyond, which applies to all students. Their interpretation of the dual interacting senses of science literacy—derived sense and fundamental sense—is supported by an analysis of the science education reform documents in English-speaking countries and the analysis of cross-curricular reforms in the United States that emphasize (Ford, Yore, & Anthony, 1997; Hand, Prain, & Yore, 2001):

1. The meaningful understanding of knowledge about the big ideas or unifying concepts/themes of science like the nature of science, scientific inquiry, and major conceptual themes in the biological, earth-space and physical sciences, and

2. A literacy component that stresses the cognitive abilities, critical thinking, and habits of mind to understand the big ideas in science, to inform and persuade others about these ideas, and to participate more fully in the public debate about STSE issues.

The mastery and achievement associated with these component parts are dictated by the level of science literacy desired—general for all citizens and elite for citizens who will be engaged as future science-related professionals.

Models of Learning, Discourse, Reading and Writing

The analysis of the current reforms in language arts and science also revealed pedagogical assumptions about learning from sensory experience, discourse and processing or producing text; teaching, and assessment that converge on interactive-constructivist learning, inquiry-oriented teaching, and authentic assessment (Ford, Yore, & Anthony, 1997). There are mixed opinions about constructivism, the type of inquiry instruction, and the value of authentic assessment in the education literature. The first Island Conference appeared to find agreement that these three components needed alignment, but a survey of models of science learning, discourse, reading, and writing revealed that no such common framework existed. However, two decades ago Osborne and Wittrock (1983) hinted of such a unified model when they stated:

> To comprehend what we are taught verbally, or what we read, or what we find out by watching a demonstration or doing an experiment, we must invent a model or explanation for it that organizes the information selected from the experience in a way that makes sense to us, that fits our logic or real world experiences, or both. (p. 493)

Analysis of the current views of reading and writing indicates that these cognitive enterprises are considered to be interactive and constructive as readers make sense of text and writers build knowledge while they produce text (Keys, 1999; Ruddell & Unrau, 1994; Yore, 2000). Central in these pedagogical considerations is the roles that activity, prior knowledge, metacognition, critical thinking, reflection, and explicit instruction play in the teaching-learning enterprise. However, the role of activity in learning science has been of concern to science educators for some time and recently Blank (2000) has provided a concise and pointed illustration of 'activitymania' in which teachers and students equate learning with doing. In this context, both teachers and students believe that the completion of an inquiry activity results in understanding and, furthermore, that any lack of understanding just requires another activity. Blank found that providing students with opportunities to discuss their results and knowledge claims regarding their intelligibility, plausibility, and utility (epistemic awareness of conceptual growth and change) resulted in significantly higher retention and delayed retention test scores for the experimental group over the normal learning cycles control group of grade 7 students. She also detected a difference in the purposefulness of oral discourse between the two groups with the experimental group being more engaged and thoughtful.

Issues of thinking about learning, talking, reading and writing while performing these cognitive operations to improve the performance of the operation involve metacognition, which incorporates awareness of the declarative, procedural, and conditional knowledge about the operation and the real-time executive control of the operation (planning, monitoring, and regulating actions). Metacognitive awareness and executive control are illustrated in Blank's considerations of the epistemic considerations to justify and the decision to add ideas or modify the architecture of the conceptual network NOT SURE WHAT THIS LAST EXPRESSION MEANS. Metacognition appears to play an interface-retrieval-transportation role between prior knowledge in long-term memory, sensory input in short-term memory, and knowledge construction in working memory of the Osborne and Wittrock generative model. Koch (2001) stated:

> Metacognition is a technique that tests reality by checking, monitoring, coordinating, and controlling deliberate attempts to execute learning activity. Metacognition is a hidden level of behavior that involves focusing on conscious knowledge about knowledge and its relation to intellectual performances. (p. 760)

According to Koch's research, students who were required to complete metacognitive tasks that involved … NEED EXAMPLE and provide associated instruction while reading physics text demonstrated significantly higher comprehension of the textual message than students who were not required to complete similar tasks and were not provided with reading instruction. It is apparent that language and science research and instruction involve both learning the forms and functions of science discourse and using strategically presented discourse opportunities to learn science—illustrating the symbiosis between the fundamental and derived sense of science literacy.

Roles of Discourse in Science Education

Yerrick and Roth (2005) provided a broad set of sociolinguistic, sociocultural, and sociopolitical perspectives on discourse communities in science classrooms to address a range of issues that included:

- Tensions between literacy education and science education.
- Similarities and differences between discourse in authentic and school science.
- The need to engage students in BETTER? the technological-scientific epistemologies, thinking, and communications emphasized in the current reform goal of science literacy for all.
- The crossing-borders that students face as they move among home, school, and science languages.
- Curricular, instructional, and assessment approaches that consistently recognized the roles of language in doing, reporting, teaching, learning, and utilizing science.

In their work, as with that of Roth and Barton (2004), interpretations of the function of discourse frequently included a social justice dimension that had a specific political agenda not necessary in the consideration of the importance of language in doing and learning science (Yerrick & Roth, 2005). In reflecting on this sociopolitical agenda, Duschl (2005) stated, "[to] be honest, I find it difficult to embrace or endorse several of the perspectives, … perspectives that are at times against schools, against school science, against scientific inquiry, and against academic science." (p. ix). The perspective in this special issue of the *International Journal of Science Education* does not disregard the importance of access, opportunity, gender equity, and fairness and does not purpose a radical stance about science, schooling, and science teaching. Gee (2005) stated:

> No domain represents academic … language better than science. Science makes demands on students to use language, orally and in print, as well as other sorts of symbol systems, that epitomize the sorts of representational systems and practices that are at the heart of higher levels of school success. (p. 19)

Science literacy requires in a fundamental sense that people be proficient in science language, thinking, and emotional dispositions as well as in a derived sense that they understand the nature of science, the big ideas of science, and the relevance of the interactions among science, technology, society, and environment (Hand, Prain, &

Yore, 2001; Norris & Phillips, 2003). Gee (2005) believed, as did many authors of ??BETTER this special issue, that the fundamental sense influences achievement of the derived sense of science literacy, that acquisition of the science language involves the acceptance that there will be losses in their home language, that science language is situated in—and the enculturation into—a science discourse community that is facilitated by a more proficient member of that community, and that normal social conversation and home (lifeworld) language may be negative influences on achievement of science literacy. No effective science education program would be complete if it did not support students in acquiring the facility of oral science language and the ability to access, produce, and comprehend the full range of science text and representations. Learning how to talk, write, and read science frequently requires the embedding of explicit language tasks and instruction into science inquiry to enhance the fundamental sense of science literacy that can be used to enhance the derived sense of science literacy—talking, writing, and reading to learn science (Yore, 2000).

Oral discourse is necessary, but not sufficient, to do and learn science (Norris & Phillips, 2003). The detailed associations among data, background information, warrants, evidence, claims, counterclaims, and rebuttals of authentic science require a print record to document ownership of these claims, to reveal patterns of events and arguments, and to connect and position claims within canonical science (intertextuality). Science learning and discourse in classrooms connect classroom talk, informal personal experiences, everyday terms, and concrete experiences; knowledge constructions and established knowledge claims become stored in print and digital sources. The connection to personal experience and spontaneous language respects and anchors prior knowledge and home language in science instruction, rejects the deficit interpretation of the two-language or three-language problem faced by learners of science as they move among home, instruction, and science languages, enhances learning, and justifies the further connections of classroom learning to canonical information sources (Collins, Palincsar, & Magnusson, 2005; Gee, 2005; Varelas, Pappas, & Rife, 2005).

Collins et al. (2005) outlined a pragmatic framework based on a long-term effort to articulate the roles of language in science inquiry learning. The framework focused on the construction of substantive knowledge in science classrooms based on syntactic knowledge, authentic science inquiry, and practical pedagogy that involved investigative, communicative, and explanatory (consistency, coherence, completeness) considerations. These considerations provided scaffoldings for inquiry and knowledge construction in the form of explicit instruction about the physical tools, introduced conceptual tools, and helped students clarify and extend their thinking. Surprisingly, Collins et al. provided no explicit consideration of metacognition and instruction about specific science discourse functions, namely, argumentation, reading, and writing. Indeed, much of the pedagogical and pedagogical-content knowledge, strategic discourse knowledge and the classroom practices advocated are not articulated in the current science education reforms nor are they part of most science teacher education and professional development programs.

Teacher Education and Professional Development

Some science education reform documents have gone beyond the traditional prescriptions of learning outcomes to articulate the importance of teachers, teaching, and hands-on/minds-on inquiry learning as influences on students' science literacy (Shymansky, Yore, & Anderson, 2004). These reform documents provide visions not only of what we should teach, but also how we should teach and how we should teach teachers to teach. Unfortunately, there has been little consideration of the language component of science literacy and little cross-disciplinary considerations between science education and language arts reforms. The teacher education and professional development task involves both the promotion and facilitation of inquiry science teaching and scientific language teaching among preservice and inservice teachers who have little personal experience in such teaching environments, either as a learner of science or as a teacher of science.

For the past 50 years, incorporating language in science into teacher education programs has been somewhat limited. The 1960s reforms were very successful in eliminating text from elementary science instruction to the point that many schools no later provided science textbooks or supplementary informational books for the science inquiry modules. In more recent times, however, there has been a noticeable change in attitude on this issue by state departments of instruction and publishing companies that now require or provide explicit language instruction and supplemental print materials for inquiry modules. The re-introduction process has been somewhat successful in elementary teacher programs, especially with the K-3 component. However, inclusion in secondary teacher programs has been less successful because it is difficult to convince science majors in teacher education programs that language is an essential part of doing science. Nevertheless, some teacher education programs require content reading courses of all disciplines while other universities require writing intensive courses of all major areas to improve general literacy (Yore, Bisanz, & Hand, 2003).

Studies of integrated language arts and science—in which teaching engages all students in a quest for science literacy and where teachers are able to plan, design, and manage curriculum that promotes the procedures and intellectual rigor of scientific inquiry and assesses their own teaching and student learning—have been somewhat limited. Teacher education courses have demonstrated potential, but finding appropriate instructional teams has been problematic (Ackerson & Flanigan, 2000). Professional development projects have found that effort must be given to both inquiry teaching and embedded language issues, the direct link to student achievement is somewhat weak, and the development of these teaching strategies takes longer than many anticipated (Shymansky, et al., 2004). Loucks-Horsley and Matsumoto stated "influences on the relationship between professional development and student learning" that considers school cultural, parental, policy and leadership factors embedded in state, provincial, and national contexts are critical elements in the teaching-learning equation (1999, p. 260). The depth of teacher changes is believed to be related to the duration of professional development efforts (Shields, Marsh, & Adelman, 1998; Weiss, Montgomery, Ridgway, & Bond, 1998), but recent studies question this implied linear relationship (Shymansky, et al., 2004; Yore, Shymansky, & Anderson, 2005). Supovitz and Turner (2000) found that teachers experiencing less than 40 hours of professional development often reported inquiry-based practices and investigative classroom cultures that were less positive than teachers receiving no professional development. The researchers found that not until teachers received more than about 80 hours of professional development did their reported inquiry practices and investigative culture significantly improve. Based on these data, it seems clear that short-term research studies seeking to demonstrate improved classroom practice or to establish a link between improved practices and student achievement are not likely to accomplish their goals.

Summary Comments/Synthesis

The collection of articles in this special issue captures the diverse perspectives and lack of convergence illustrated in the above discussion and detected once more at a recent planning session for the second Island Conference, "Gold Standard(s) for Quality Research in Science Literacy (Shelley & Hand, 2005). This article attempts to provide a synthesis of this collection of articles, to capture the deliberations of the first Island Conference that focused on empowering research and informing instruction, and to provide a sketch of future avenues for research, classroom practice, and teacher education. The editors have organized the seven articles in this special issue of the *International Journal of Science Education* into foundational issues and application studies.

Foundations of Language and Science Research and Instruction

Klein (this issue), Prain (this issue), and Yore, Florence, Pearson, and Weaver (this issue) enunciated the foundation of a science literacy position for language and science education research within a framework of authentic science, contemporary cognitive science, and language and literacy pedagogy. The underlying goal of the first Island Conference was to stimulate convergence; however, the evidence from these foundation articles showed that this did not fully happen. Nevertheless, these articles are not in total disagreement; rather, they emphasize the varying importance of language and intellectual demands in cognition, in doing science, and in writing to learn science.

The first-generation interpretation of cognitive science closely parallels the role of language in a traditional view of the nature of science and in genre interpretation of science writing. This interpretation stresses language as a window into thinking in which thoughts occur and language follows and that learning the discourse and form-function of written science are prerequisites to understanding science and being science literate. Collectively, this constellation of ideas supports learning how to talk, write, and read science using direct instruction.

The second-generation of cognitive science emphasis on narrative discourse, and analogical and metaphorical thinking closely parallels the diversified writing-to-learn science perspective in that language shapes and influences thought and knowledge construction. This constellation of ideas supports the use of a variety of writing types to facilitate the emergence of ideas found in partially formed oral utterances and to help consolidate a learner’s embryonic text production and understandings. Participation in such a discourse community would situate the learning of science and help enculturate the participants into the science discourse and practice illustrated by modern views of science.

Collectively, Klein, Prain, and Yore, et al. illustrated the range of views on cognitive, pedagogical, ontological, and epistemological issues. Each of these perspectives is explicitly articulated to help researchers appreciate the complexity of language and science research and its classroom applications. These authors accept the border crossings encountered as people move from their home language to an instructional language on their way to acquiring scientific language as a central consideration in facilitating and achieving science literacy. The underlying logic, the form of language, and the role of language in thinking and knowledge construction are three dimensions that arise from a synthesis of these perspectives and the embedded contrasts, namely thetraditional view of science/modern view of science; first-generation cognitive science/second-generation cognitive science; and epistemic orientation of writing/diversified orientation of writing.

Expanding on these three dimensions, the traditional view of science posits inductive and deductive logic that guides rational thinking and language as a reporting device of thought that functions to document the time-series actions of inquiry. Alternatively, the modern view of science posits abductive and hypothetico-deductive logic that guides hypothesis formation and testing, and language as a cognitive tool (technology) that interacts with cognition to shape and report knowledge claims. The first-generation of cognitive science posits a straightforward predictable computer-like logic and discipline-specific, expository language that reflects and serves as a conduit of thinking. In comparison, the second-generation cognitive science posits fuzzy logic, narrative, and metaphoric language that influences thinking and connects loose networks of situated ideas. The epistemic orientation of writing posits a disciplinary logic that reflects the traditional nature of science and functional language and genre that accurately report and facilitate scientific understanding. In opposition to this is the diversified orientation of writing which posits a flexible and pragmatic logic and a flexible mixture of natural and disciplinary language that helps bridge experience-to-talk, talk-to-text, and text-to-talk, and enhances motivation and engagement in learning.

On the surface, there is no great convergence flowing from these foundational articles other than that the various genre and writing tasks might be justified by different interpretations of science, learning, and pedagogy and that the purpose, task, context, and learners need consideration in making such decisions. The purposes and outcomes associated with these genre and writing tasks will likely differ and their effectiveness in achieving the associated purposes and outcomes are not fully established. Additional research is needed to document how students learn to talk, write, and read science (the fundamental sense of science literacy), and considerable emphasis needs to be focused on the link between talking, writing, and reading and science understanding (the derived sense of science literacy).

The three foundation articles suggest that researchers and teachers must consider the disciplinary, psychological, and pedagogical perspectives in advocating and designing both learning the discourses of science and utilising these discourses to learn science. This general claim applies to learning to talk and argue science, talking and arguing to learn science; learning to read science and reading to learn science; and learning to write science and writing to learn science. One approach or task might be more appropriate to enhance motivation and engagment, while other approaches and tasks might be better to enhance writing strategies, discourse knowledge, or domain knowledge of science.

Other common considerations across these three articles are the roles of analogies and metaphors in making sense of the natural world and the role of metacognition in investigating problems, constructing knowledge claims, and explaining causes within patterns of naturally occurring events. Klein and Prain stress the importance of analogues and metaphors as cognitive and linguistic tools to deliver creativity and abductive thinking in doing and learning science. Although the history of science is replete with analogies and metaphors that helped move scientists' thinking forward (for examples in biology, see Venville & Treagust, 1997), Yore et al. were unable to document scientists' explicit use of these cognitive devices in constructing understanding of their science inquiries other than in communicating ideas to less expert associates. However, metacognition during scientific inquiry in laboratories and classrooms, preparing and delivering oral and written arguments, seeking information from print and digital sources, and writing science text were central to scientists doing science, students learning science, and people writing about science.

Language in Science Learning, Assessment, and Professional Development

The first Island Conference presentations considered a wide variety of practical issues involving oral discourse, written text, instructional approaches, authentic assessment, teacher education, and professional development. The four articles by Hildebrand (this issue); Hohenshell and Hand (this issue); Simon, Erduran, and Osborne (this issue); and Rijlaarsdam, Couzijn, Janssen, Braaksma, and Kieft (this issue) included in this section address most of these concerns (assessment, oral and written language acquisition, writing to learn). While there is some evidence that talking-to-learn, reading-to-learn, and writing-to-learn techniques support the derived sense of science literacy, there remains the need for more empirical research investigating the classroom environment, instructional context, teaching strategies, assessment techniques, and science achievement (Yore, Bisanz, & Hand, 2003). Collectively, these four studies consider classroom discourse, reading and writing in science, and authentic assessment involved in an interactive-constructivist context, and the outcomes of professional development and collaborative research projects to explore the implementation and learning outcomes associated with such language in science undertakings. The central trends from these studies illustrate the need to consider:

- Professional development;
- Teacher scaffolding (support for and impact on student performance);
- Importance of legitimate literacy tasks that reflect the nature of science, science as argument, the public debate about STSE issues and pedagogical considerations; and
- The need to develop authentic assessment techniques that are aligned with instruction to empower learning and inform instruction.

Simon et al. investigated the effects of a collaborative professional development project in which grade 10 teachers designed and implemented argumentation into their science classrooms over an extended period of time. These teachers were able to develop and incorporate into their teaching and subsequently into their students' learning how to use argumentation; this use included the elements of argument (claims, evidence, warrants, backing, counter-claims, rebuttals) for lessons considering STSE issues. The analysis demonstrated that teachers encouraged a variety of processes involved in argumentation and that their lessons incorporating quality argumentation encouraged higher-order processes and thinking in the students. This study illustrates an informed view of modern science as argument and of teacher support, but unfortunately it does not establish a clear connection between students' use of quality of argument and the elements of argumentation with the students' science understanding—the missing link in most professional development research (Shymansky, et al., 2004).

Hohenshell and Hand, and Rijlaarsdam, et al. focus on the proposed link between the fundamental and derived senses of science literacy, while confirming the need for teacher scaffolding in writing and reading to learn. Hohenshell and Hand build on past research about inquiry, social negotiation, writing strategies, and students' lower-level and higher-level science achievement. Two different types of laboratory reports and a final summary report for teachers and peers were embedded in science inquiry instruction. The evidence for the Science Writing Heuristic (SWH) indicated that females using the SWH performed better than males using the SWH and females writing traditional laboratory reports and that both females and males using the SWH performed better than students writing traditional reports regardless of the audience for the summary report. An open-ended survey revealed that students using the SWH were more able to describe learning as they were writing and were more likely to report the specific thinking required of both writing tasks than were the students not using the SWH.

Rijlaarsdam et al. investigated the process in which students were required to transform experience into text for a specific laboratory procedure. The students wrote directions to complete the laboratory task for their peers (instruction genre). Subsequently, peers read, performed, and evaluated the instructions provided in the student-generated laboratory manual. Judgments of successful completion of the task were used to assess the clarity and completeness of the written instructions. This treatment addressed the fundamental sense (learning how to write directions) and the derived sense (writing directions to better understand scientific procedures) of scientific literacy. The statistical analyses illustrate the impact of social negotiation of criteria among peers and the related impact on understanding scientific procedures.**[David, I cannot complete this summary until I get the final manuscript.]**

When using diversified writing tasks -- ahybrid/imaginative writing genre-- with secondary science teachers, Hildebrand found that four core assessment principles emerged from the reflections on practice, namely to:

1. Empower learning;
2. Value all facets of the intended curriculum and learning experiences;
3. Involve a variety of types and modes of assessment practices; and

4. Be transparent to students and other stakeholders in which explicit criteria for judging the quality of work are provided, understood, and utilized.

The teachers utilized these principles in their criterion-referenced assessment to design or select writing tasks and to develop analytical scoring rubrics clustered under four dimensions: scientific substance, writing product, writing process, and presentation. Two pragmatic benefits arising from these assessment practices involved the unique opportunities provided for the authentication of students' work and for the value added to empower learning and inform instruction gained through the teachers' evaluation experiences. **[David, I am speculating that Gael will make the revisions on the prescribed time line given. This section will need updating once the final manuscript is available.]**

These classroom applications illustrate some concerns in learning how to use the language of science, using language to learn, and meeting a science education agenda. Caution and effort need to be devoted to ensure a shared understanding across the research communities: diversified writing tasks (Prain, this issue) are not the same as creative writing tasks described by most teachers and do not endorse an 'anything goes' attitude in which a collection of literacy activities, which may be only appropriate for early language acquisition, are infused into science instruction. If there are no arguments to the contrary, such non-critical infusion of oral and written discourse activities will replace serious science inquiry and learning. Such use of language will destroy gains established by purposeful science inquiry approaches, such as the learning cycle and problem-based learning REFERENCE?. Indeed, there is an absence of evidence for some language tasks that might be tangentially related to the fundamental sense of science literacy having an effect on the derived sense of science literacy (Bangert-Drowns, Hurley, & Wilkinson, 2004). A critical stance must be applied in selection of language and assessment strategies and activities embedded in science instruction depending on desired learning outcomes such as abilities, habits of mind, communications, discourse strategies, or understanding of the major ideas of science. Researchers and teachers must provide compelling justifications for their beliefs, judgments, and actions based on disciplinary, psychological, and pedagogical grounds:

- Do the language tasks reflect or result in authentic science discourse, literacy for citizenship, and participation in the public debate about STSE issues?

- How do the language tasks relate to models of learning underlying the research or instructional practice?
- Do the language tasks enhance or utilize specific pedagogical assumptions involved in effective science instruction?

Further investigations are needed to provide the evidence that will help develop more theoretical frameworks and informed classroom practices. Clearly, implementation of language in science instruction requires consideration of the teacher education and professional development required.

Future Possibilities

The closing of the first Island Conference was structured around deliberative sessions focused on empowering research and informing teacher education and professional development. These deliberations were initiated by provocative presentations that opened the debate to small groups that reported back to the conference participants. Four central issues developed for the deliberations: need to develop support for a contemporary view of science literacy, the role of metacognition in science learning generally, the role of multiple representations in knowledge building and science literacy, and the need for more focused teacher education and professional development programs.

Large-scale Testing, Elaboration of Science Literacy and Educational Policy

The need to inform the public of decisions about and what influences policy in science literacy was a clear and consistent outcome of the conference deliberations.Any future research agenda needs to consider ways to inform a wider variety of educators, bureaucrats, and politicians and to capitalize on high-profile policies, conferences, and assessments. State, provincial, national, and international surveys have assessed students’ achievement in a constellation of subject areas related to science literacy—language arts, reading, writing, mathematics, and science. Without further research by science educators and literacy educators these databases may remain as untapped reservoirs of information about students’ language performance, numerical abilities, and science processes and knowledge.

One such international survey, the Programme for International Student Assessment (PISA) administered by the Organisation for Economic Cooperation and Development (OECD),now involves 15-year old student samples from more than 50 countries. The PISA concept of literacy, being much broader than the historical notion of the ability to read and write, accepts that a literate person has a range of competencies that can be “measured on a continuum, not on something that one possesses or does not possess” (OECD/PISA, 2000, p. 7). PISA considers literacy to be the knowledge and skills for adult life that are acquired through formal and informal learning over a lifetime. PISA is currently assessing reading literacy, mathematical literacy, and scientific literacy with each domain composed of three parallel dimensions: process skills, knowledge and understanding, and the context of application. Scientific literacy defined by PISA is “The capacity to use scientific knowledge, to identify questions and draw evidence-based conclusions in order to understand and help make decisions about the natural world and the changes made to it through human activity” (OECD/PISA, 2000, p. 76). The scientific processes involved in the assessment are (a) recognizing scientifically investigable questions, (b) identifying evidence needed in a scientific investigation, (c) drawing or evaluating conclusions, (d) communicating valid conclusions, and (e) demonstrating understanding of scientific concepts. The most recent publication of the PISA reported proficiency levels for mathematics literacy showing how well students perform in various mathematical content areas and also directly assessed cross-curricular competencies in problem solving. A similar study in science will be conducted in 2006 (OECD/PISA, 2004).

The PISA data and other similar data sets, such as theNational Association of Education Progress (NAEP) in the US and the international Trends in Mathematics and Science Studies (TIMSS), contain rich and connected information on students’ achievement, homes, schools, and communities that may have potential to better position science literacy in the broader context of schooling and hence directly guide policy decisions. However, although these studies have resulted in a large number of publications—specifically international and national reports, theses, dissertations, and edited books—few of these publications are published in science education research journals or presented at science education conferences and these studies have not yet had the necessary impact on the science education community (Olson, 2004).

One reason for this situation is that although the relationships between school system traits and the outcomes of schooling are of basic interest and significance to the educational policy community, the data sources and analysis approach need to be understood by the policymakers (Anderson, 2002). The elements of public education are assumed by policymakers to show influence over the key consequences and outcomes of schooling. However, these relationships are complex, involving factors other than curriculum and instruction such as student characteristics, teacher and school traits, social capital of the system, home and community characteristics, and available financial resources. These relationships have been found to be significant, but they vary across grade-levels, schools, and subject areas (NEED A REFERENCE?).

Many empirical investigations associated with this field have involved examining first-order correlations between educational indicators and test scores without desegregating the test results upon sound theoretical basis (NEED A REFERENCE?).. However, up until now, the findings have lacked persuasion, with correlations for language, mathematics, and science achievement being small, accounting for 10-30% of the variance. When a more selective language performance based text on expository text is used, much higher correlations have been claimed. Furthermore, the relationship between school and student success have been claimed, but evidence indicates that the level at which the system traits are aggregated influence the results revealing the within-school variation in student achievement is generally greater than between-school variation (Anderson, 2002).

Empirical research and quantitative analysis to link the complex and varied databases of student assessment information to policy issues of language, mathematics, and science education could lead to better understandings of the performance and quality of schools and of the relationship among language, mathematics, and science literacies. The relationship and structural patterns (Structural Equation Modeling, SEM; Hierarchical Linear Modeling, HLM; general path analyses, etc.) of these data could clarify the relationship among language arts, mathematics, and science literacy and serve as an evidential basis for educational policy. This research would investigate a set of policy-relevant issues. In order for these indicator models to enlighten participants and to expand understandings, the measures, analyses and models must be trusted by the policymakers, be school-relevant and be conducted over the long term. The results of these analyses must be clearly communicated to a broad and varied audience and in such a way that informed discussion is initiated and sustained. The frameworks and the models generated from this research and their level of commonality across data sets will enhance understandings of public school performance, help to focus policy on functional and accessible aspects of schooling, and clarify science literacy. The analysis of data from

PISA may change this situation; based on the 2000 data, countries with results less than expected have implemented changes in their science curricula and approaches to teaching (Moschner, Kiper & Kattmann, 2003).

Metacognition

Metacognition, a term first used by Flavell over 25 years ago, refers to an epistemological perspective of thinking about one's own thinking as the individual is thinking to improve his or her thinking (Rickey & Stacy, 2000) .. In this way, metacognition is linked to critical thinking and reflection-on-action. Alternatively metacognition can be considered as an awareness of one's own cognitive processes, monitoring of those processes, and regulating the processes in reference to a particular goal. From a science education researcher's perspective, metacognition deals with students' understanding and is a consideration of how their thinking influences their inquiries, actions, and learning as well as helping students develop their understanding of the scientific concepts, which in turn can lead to enhanced science literacy. Driver, et al. (1994) suggested that students need to be aware of their own thinking in order to appreciate any conceptual changes occurring in their understanding. Metacognition has the potential to be further developed and examined across a variety of learning and teaching tasks (inquiry, classroom discussion/debates, reading, writing, etc.). Metacognition can be used as an indication of the student's capacity to use scientific knowledge, to identify questions and draw evidence-based conclusions, to make critical judgments about what to believe or to do, to make decisions about the natural world and the changes made to it through human activity, and to reflect on these actions. This interpretation hints at a convergence of learning, metacognition, critical thinking, and reflection.

Metacognition is composed of two elements: metacognitive knowledge and regulation of cognition. The primary focus of research in metacognition has been in the area of metacognitive knowledge, awareness, and conscious use of this knowledge. Metacognitive knowledge consists of the knowledge that has been acquired regarding one's own cognition as it relates to many diverse experiences: declarative knowledge (what), procedural knowledge (how), and conditional knowledge (why and when). Declarative knowledge refers to the knowledge that one has about oneself as a learner and the factors that affect performance. Procedural knowledge is knowledge about strategies that can be employed to improve performance. Conditional knowledge refers to an awareness of why, when, and where to use a particular strategy. Future research needs to expand into the consideration of a wider variety of cognitive operations involved in doing and learning science, into real-time negotiation of these cognitive operations (executive control), and in developing a generalized model of learning.

Earlier, Gunstone (1994) has argued that metacognition is a central issue to constructivist perspectives of learning, such as conceptual change where learners need to recognize their existing ideas, evaluate them, and then decide whether or not to reconstruct them based on epistemic considerations of dissatisfaction, intelligibility, plausibility, and fruitfulness. Similar efforts have been made in science reading (Yore, Craig, & McGuire, 1998) and science teaching (Zohar, in press); but the research needs to be expanded into science argument, writing, inquiry, self-assessment, reflection, critical thinking, and other operations related to science literacy. Consequently, this research needs to move beyond articulating and assessing metacognitive awareness (declarative, procedural, and conditional knowledge) to investigate the real-time executive control (strategic planning, monitoring progress, and regulating actions) of the wide array of cognitive operations central to science literacy involved in doing science, learning science, and participating in the public debate about STSE issues. Creative methods must be developed and verified to document setting purpose, planning, heuristic or solution approach, accessing prior strategic, discourse and domain knowledge, assessing progress, reflecting on the evaluation, making critical decisions, and activating alternative approaches (Baker, 2003).

Some effort has started to be applied to develop models of academic learning that incorporate contemporary views of cognitive science (Alexander, 2003; Chi, 2003; Hidi, 2003). Their approaches have placed ontological assumptions, interest, and prior knowledge in priority positions. A potential fruitful step for science education and science literacy is to modify the generative learning model (Osborne & Wittrock, 1983) to include metacognition and a richer variety of learning tasks and information sources. This interactive-constructivist model would place metacognition as an interface among the external input, prior knowledge, and knowledge construction continuum. Metacognition would orchestrate the input of information, retrieval of prior knowledge from long-term memory, and meaning making in working memory. The model would need to include information input from direct experience, oral discourse, and digital and print stored sources. Consequently, teaching science metacognitively requires that teachers be aware of the sources and characteristics of student alternative conceptions, to select strategies to overcome their alternative conceptions, and to monitor/evaluate the extent to which such conceptions have been replaced by scientific conceptions or integrated into conceptual beliefs more like those of scientists.

Multiple Representations

Science representations—such as models, analogies, equations, graphs, diagrams, pictures, and simulations—are exhibited in a variety of forms/modes—such as verbal, mathematical, visual, and actional-operational (Lemke, 1998). Different types of representations are used to enhance conceptual understanding and improve communication and a considerable amount of research has been conducted to investigate the effect of a single representation. However, little research has been conducted on how all these representational strategies can be unified by a multi-representational framework or in the enhanced cognition that occurs during the transformation from one representation to another representation or one mode to another mode (experience-to-talk, talk-to-text, etc.). Of interest are how these different representations or representational transformations can be used in science teaching and learning to promote metacognition and in turn promote the fundamental and derived senses of science literacy. Using different representations can make difficult scientific concepts more intelligible to students by increasing the likelihood of progressing towards more sophisticated conceptual learning (Posner, Strike, Hewson, & Gertzog, 1982). In a similar manner, writing research has demonstrated the effects of presentational transformations as writers move from research question to evidence to claim or from data table to graph to descriptive text (Hand, Prain, & Yore, 2001).

Much of science is abstract and interpretive, and the representations of ideas that learners encounter have a profound effect on their understanding and on the mental model they construct. The broader definition of a scientific model includes a variety of representations that may or may not accurately portray all aspects of the phenomenon (Gilbert, 1999). There is a need for representational competence in science literacy including an understanding of the features, merits, and differences of each form in linking the various representations (Kozma, 1997). Computers, spreadsheets, graphing packages, and three-dimensional modeling and animation software allow conversion of data to graphs to models with little physical effort.

However, these conversions and illustrative of the difficult tasks of mental transference that are given little consideration in school or university and yet they are pivotal in developing mental models (Copolo & Hounshell, 1995). Similarly, the ‘mental gymnastics’ of slipping and sliding from one level of interpretation to another, especially in chemistry, is a necessary skill in understanding (Johnstone, 1982).

Ainsworth (1999, p. 131) stated that “a common justification for using more than one representation is that it is more likely to capture a learner’s interest and, in so doing, play an important role in promoting conditions for effective learning.” Ainsworth’s research primarily involved computers and multimedia, but multiple representational learning environments are ubiquitous and exist outside fields of technologically enhanced learning environments.

[Insert Figure 1 here]

The left-hand side of Figure 1 illustrates the use of representations that contain complementary information or support complementary cognitive processes. Examples of this function are when different representations, such as tables or graphs, provide equivalent information; but for some learners, one mode of representation may be more easily assimilated than the other. Ainsworth (1999, p. 137) stated “where learners are given the opportunity to use multiple external representations, they may be able to compensate for any weaknesses associated with one particular strategy by switching to the other.” The implication is that science teachers should present to students different representations that express equivalent information because each makes salient different aspects of the situation. There are rarely situations where a single representation, such as tabulated data, is effective for all tasks.

The middle part of Figure 1 illustrates how multiple representations can be used to help learners develop a better understanding of a conceptual domain by using one representation to constrain their interpretations of a second representation. For example, learners may be presented with a familiar analogy to support their interpretation of a physical phenomenon of which they are less familiar and which is more abstract.

The right-hand side of Figure 1 relates to the claim that multiple representations lead to deeper understanding of concepts that may include promoting an abstraction, encouraging generalization, and teaching the relation between representations. For example, domain knowledge may be extended when learners know how to interpret a velocity time graph to know whether or not a body is accelerating and can subsequently extend their knowledge to present tables and acceleration-time graphs.

Teacher Education and Professional Development

Science literacy, as illustrated in this special issue, and the interactive-constructivist model of learning and related teaching approaches outlined suggest that teacher education and professional development will need to assign a much more important role to language in doing and learning science and in science literacy. Teachers who have not experienced language as a cognitive tool in the construction of knowledge must be convinced that such a function is justified. Moving experience to talk to text, facilitating arguments to achieve deeper understanding, and the utility of STSE issues and debates to achieve science literacy for citizenship require different interpretations of teaching, the role of teachers, and the roles of information sources (inquiry experience, interpersonal interactions, printed text, digital databases, Internet, etc.). Current science teachers do not see themselves as language teachers, school departmentalized structures physically and psychologically separate teachers of science and language, and students resist integration of content areas and disciplinary abilities. Language as a cognitive technology needs to be embedded in all disciplines as schools stress contemporary literacies. Effort is also needed to move teachers toward a more justifiable, modern view of science (Yore, et al., this issue).

Some positive teacher education and professional development experiences have been reported (Anarel, Garrison, & Klentschy, 2002; Collins, et al., 2005; Klentschy & Molina-De La Torre (2003); Romance & Vitale, 1992; Shymansky, et al., 2000, 2004; and Yore, et al., 2005), while other work with larger groups of teachers from several grade levels utilizing the argument, SWH, and content reading have revealed promise (Hand, et al., in progress; Holden & Yore, 1996; Simon, et al., this issue). These programs and projects have focused on implementing language in science inquiry in elementary, middle, secondary, and college/university classrooms. Teachers have had to accept that less instructional coverage can result in higher science literacy and that they have had to develop a metacognition of teaching and reflective practice. Effective and exemplary teaching exists; these teachers need to be located and encouraged to collaborate with future research setting policy and practice in future conferences. Teacher education and professional development programs must be based on more inclusive models of learning and must consider instruction and authentic assessment that empowers learning and informs teaching (Hildebrand, this issue).

Immigration worldwide has resulted in multicultural classrooms where the language of instruction is not the dominant home language. By necessity, teachers have had to address the three-language problem and help students navigate among home language, instructional language, and science language. This has required consideration of discourse and explicit instruction to learn to talk, read, write, represent, and interpret science. Once these fundamental language abilities are in place, they need to be used to learn science content—the derived sense of science literacy.

Closing Comments

The intention of the first Island Conference was to bring together scholars from a range of disciplines, each of whom had a direct or an indirect interest in research in scientific literacy. Colleagues brought to this meeting various views about scientific literacy, and these were shared in robust discussions both in the plenary sessions and in the small breakout groups. Throughout the conference, the organizers and the authors of this article made every possible attempt to encourage the participants to maintain a critical interest in the ontological, the epistemological, the linguistic, and the pedagogical considerations of language in science literacy. In this final article of the special issue of the *International Journal of Science Education,* we have attempted to illustrate how these four considerations of scientific literacy can be brought together in order to provide not only a summary arising from our deliberations, the descriptions and analyses of findings from published research and our formal and informal (often into the small hours of the morning) but also to illustrate some possibilities for effective future research that will position the field to have both implications for practice and policy.

The central spirit of the first Island Conference was to enhance science literacy by embedding language instruction and tasks in ongoing science inquiries. There was no hidden agenda to divert instructional time from science to language arts. It was a sincere belief that achievement of the fundamental sense of science literacy will lead to achievement of the derived sense of science literacy. This connection still lacks evidence, but continued research and implementation of verified language instruction and tasks will likely document its existence. It is this and other such issues that will anchor the search for appropriate methodologies and to establish gold standard(s) for research in science literacy at the second Island Conference in Victoria, BC, Canada, October 27-30, 2005 (Shelly & Hand, 2005).

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