SCIENCE LITERACY FOR ALL STUDENTS: LANGUAGE, CULTURE, AND KNOWLEDGE ABOUT NATURE AND NATURALLY OCCURRING EVENTS

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Abstract. It is important that the first, native, home, or mother tongue language (L1), cultural and personal beliefs, ontological assumptions, and epistemological beliefs of students be explicitly considered in teaching and learning environments where a different language of instruction (L2) and an English-dominated scientific enterprise (L3) are commonplace. Teaching in today's multicultural classrooms in most countries requires understanding of the three-language issue. Research inquiries into language, literacy, and science issues must consider the values, beliefs, and practices and the traditional knowledge about nature and naturally occurring events embedded in language and culture. This introductory piece provides a reference frame for the roles of the nature of western science, language, and culture for these considerations in an attempt to produce insights for culturally sensitive curricula and effective constructivist teaching. Some authors will question the explicit and implicit values of western science as outlined here, which is the central purpose of this special issue. Cultural restoration, environmental literacy to survive, and other priorities are competing goals with acculturation into western science discourse communities for some peoples.

Keywords: epistemology, nature of western science, ontology, science literacy, scientific language/discourse

Dutch
Samenvatting [Translated by Tanja Janssen].
Expliciet aandacht besteden aan de eerste taal, thuistaal of moedertaal (L1) van leerlingen, en aan hun culturele en persoonlijke opvattingen, ontologische vooronderstellingen en epistemologische opvattingen, is belangrijk in leer- en onderwijsomgevingen waarin een andere instructietaal (L2) en een door het Engels gedomineerde wetenschappelijk bedrijf (L3) gemeengoed zijn. Onderwijs geven in de multiculturele klassen van vandaag vereist inzicht in de kwestie van de drie talen. Onderzoek naar kwesties op het gebied van taal, geletterdheid en wetenschap zou zich moeten richten op de waarden, opvattingen en praktijken en de traditionele kennis over natuurlijke processen, ingebed in taal en cultuur. Deze inleiding verschaft een kader voor de rollen van westerse wetenschap, taal en cultuur. Getracht wordt inzichten te genereren voor cultureel sensitieve curricula en effectief constructivistisch onderwijs. Sommige auteurs

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zullen vragen stellen bij de expliciete en impliciete waarden van westerse science zoals hier geschetst; dit is het hoofddoel van dit themanummer. Culturele restauratie, geletterdheid om te overleven in een omgeving, en andere prioriteiten zijn doelen die concurreren met acculturatie in westelijke wetenschappelijk 'discourse'.
Keywords: epistemologie, aard van westerse science, ontologie, wetenschapstaal

French

Résumé [Translated by Laurence Pasa].
Il est important que la langue première, langue maternelle ou langage de la maison (L1), comme les croyances personnelles et culturelles, les présupposés ontologiques et les représentations épistémologiques des élèves soient explicitement considérés dans les situations d'enseignement-apprentissage, où un langage scolaire différent (L2) et une culture scientifique dominée par l'Anglais (L3) sont d'usage. De nos jours, l'enseignement dans les classes multiculturelles de la plupart des pays nécessite de considérer ces trois langages. Les recherches sur le langage, la littéracie et l'apprentissage des sciences doivent tenir compte des valeurs, des représentations et des pratiques, ainsi que des savoirs traditionnels sur la nature et les phénomènes naturels inscrits dans la langue et la culture. Ces éléments d'introduction fournissent un cadre de référence pour l'étude de l'impact des caractéristiques de la science occidentale, du langage et de la culture, dans une réflexion visant des programmes d'enseignement culturellement pertinents et des pratiques d'enseignement constructivistes efficaces. En accord avec la visée centrale de ce numéro spécial, certains auteurs interrogeront les valeurs explicites et implicites de la science occidentale évoquées ici. Pour certaines personnes, la reconnaissance culturelle, la littéracie fonctionnelle et d'autres priorités sont des objectifs concurrents de l'acculturation avec le discours scientifique des communautés occidentales.
Mots-clés: épistémologie, caractéristiques de la science occidentale, ontologie, apprentissage des sciences, langage/discours scientifique

Italian

Abstract. [Translated by Manuela Delfino].
È importante che la prima lingua (lingua natia, lingua madre, L1), che le credenze personali e culturali, che gli assunti ontologici, e le credenze epistemologiche degli studenti siano esplicitamente presi in considerazione in ambienti di apprendimento e insegnamento in cui la lingua di insegnamento usata sia diversa (L2) e in cui sia comune che l'inglese (L3) domini l'attività scientifica. Insegnare nelle classi multiculturali al giorno d'oggi nella maggior parte dei paesi richiede la comprensione di del problema delle tre lingue. I programmi di ricerca su lingua, alfabetizzazione e specifici problemi scientifici devono tenere in considerazione i valori, le credenze e le pratiche e la conoscenza tradizionale della natura e degli eventi che accadono in natura radicati nella lingua e nella cultura. Questo contributo introduttivo fornisce una cornice di riferimento per i ruoli della natura nella scienza, nella lingua e nella cultura occidentali, nel tentativo di proporre idee per curricula attenti alle differenze culturali ed efficaci per un insegnamento costruttivista. Alcuni autori solleveranno dubbi sui valori espliciti e impliciti della scienza occidentale delineati in questo intervento, e questo è lo scopo di questo numero speciale della rivista. Per alcune persone, la restaurazione della cultura, l'alfabetizzazione ambientale finalizzata alla sopravvivenza dell'ambiente e altre priorità sono obiettivi in competizione con quello dell'acculturazione nel discorso interno alle comunità scientifiche occidentali.

Polish

Streszczenie Translated by Elzbiéta Awramiuk]
To ważne, aby w szkolnym środowisku, w którym powszechne są inny język nauczania (L2) i zdominowane przez język angielski naukowe podejście (L3), otwarcie szanować uczniowski pierwszy, domowy, ojczysty język (L1), kulturowe i indywidualne wyobrażenia uczniów, ich ontologiczne założenia i epistemologiczne przekonania. Nauczanie w dzisiejszych wielokulturowych klasach w większości krajów wymaga posługiwania się tymi trzema językami. W badawczych dociekaniach dotyczących zagadnień języka, umiejętności czytania i pisania oraz nauk ścisłych należy pamiętać, że wartości, przekonania i zwyczaje oraz tradycyjna wiedza o przyrodzie i naturalnie występujących wydarzeniach są zanurzone w języku i kulturze. Niniejsze wprowadzenie zawiera ramy odniesienia dotyczące roli zachodniej nauki, języka i kultury w tych rozważaniach, ramy niezbędne do zrozumienia programów kulturowo wrażliwych i efektywnego konstruktywistycznego nauczania. Niektórzy autorzy będą kwestionować naszkicowane tutaj eksplicytne i implicytne wartości zachodniej nauki, które są głównym przedmiotem niniejszego

numeru specjalnego. Dla niektórych ludzi ochrona kultury, wiedza o środowisku potrzebna, aby w nim przetrwać, oraz inne priorytety są konkurującymi celami z akulturacją do społeczności zachodnionaukowego dyskursu.
Słowa-klucze: epistemologia, charakter zachodniej nauki, ontologia, podstawy naukowej wiedzy o świecie, naukowy język / dyskurs

Portuguese

Resumo: [Translation Paulo Feytor Pinto].
É importante que a primeira língua ou língua materna (L1), a cultura, as convicções pessoais, os pressupostos ontológicos e as crenças epistemológicas dos estudantes sejam explicitamente consideradas nos contextos de ensino e aprendizagem em que é frequente a língua de instrução não ser a língua materna (L2) e em que a reflexão científica é dominada pelo inglês (L3). Ensinar hoje, em salas de aula multiculturais, obriga, em muitos países, a ter em conta esta questão das três línguas. A investigação sobre línguas, literacia e questões científicas deve considerar os valores, as crenças, as práticas, o conhecimento tradicional acerca da natureza e os eventos naturais fundados na língua e na cultura. Este trabalho introdutório constitui um quadro de referência sobre os papéis da natureza da ciência ocidental, da língua e da cultura na tentativa de produzir contributos para currículos culturalmente sensíveis e para um ensino construtivista efectivo. Alguns autores porão em causa os valores implícitos e explícitos da ciência ocidental aqui veiculados e que são o cerne desta questão. Reabilitação cultural, literacia ambiental e outras prioridades competem com o objectivo de aculturação da ciência ocidental presente no discurso de muitas comunidades.
Palavras-chave: epistemologia, natureza da ciência ocidental, ontologia, literacia científica, discurso/linguagem científica

Spanish

Resumen. [Translated into Spanish by Alejandro Arrington from Benemérita Escuela Normal Veracruzana, Mexico]
Acercamiento al estudio de las ciencias para todos: lengua, cultura, y conocimiento sobre la naturaleza y los eventos naturales
Es importante que la lengua materna, lengua nativa, de casa o primera lengua (L1), las creencias culturales y personales, suposiciones ontológicas, y creencias epistemológicas de los estudiantes sean considerados de manera explícita en los contextos de enseñanza aprendizaje donde coexisten una lengua de instrucción diferente (L2) y una actividad científica dominada por la lengua inglesa (L3). La enseñanza en los salones multiculturales de hoy en día en la mayoría de países requiere una comprensión de la problemática de las tres lenguas. La investigación sobre lengua y la introducción al conocimiento de las ciencias deben considerar los valores, creencias, y prácticas, así como los saberes tradicionales acerca de la naturaleza y los eventos naturales propios de la lengua y la cultura. Este documento introductorio provee un marco de referencia para el estudio del papel de la naturaleza de la ciencia, la lengua y la cultura occidental. Para tales consideraciones, este documento representa un intento de producción de proposiciones para un currículo sensible al contexto cultural y la enseñanza constructivista efectiva. Algunos autores cuestionarán los valores explícitos e implícitos de la ciencia occidental como se menciona aquí, lo cual es el propósito central de este documento. Para algunos grupos, la recuperación de la cultura, el conocimiento del medio ambiente para la sobrevivencia y otras prioridades son metas que compiten con la aculturación en las comunidades discursivas científicas occidentales.
Palabras clave: epistemología, naturaleza de la ciencia occidental, ontología, acercamiento al estudio de las ciencias, lengua/discurso científico.

1. INTRODUCTION

The ‘First Island Conference’ (NSF Conference Grant #REC020002) revealed that it is nearly impossible and definitely unwise to consider the relationship between language and knowledge about nature and naturally occurring events without considering the ancillary issues associated with language-culture (i.e., values, beliefs, practices, ontology, epistemology, and other embedded sociocultural issues). The multicultural nature of classrooms around the world illustrates the interface amongst different languages, cultures, and knowledge systems about nature and naturally occurring events (sciences). Furthermore, just about every science language learner (ScLL) – regardless of their home language's alignment with the language of instruction – faces similar problems as a second language learner (SLL) navigating and negotiating the border crossings between home, school, and science discourse communities (Yore & Treagust, 2006).

I recall distinct experiences from my own elementary school education some 55 years ago where my home language, school language, and science language were misaligned. Raised by a single mother who spoke non-standard English, in which subject-verb misalignment, invented words, slang, and other grammatical errors were common, I was in culture shock upon entering a school culture that used standard English and an unfamiliar world of Dick, Jane, Spot, and Fluff (characters in a popular 1950s reading program). I was becoming somewhat comfortable with this new language and culture and in developing a school identity when I encountered interpretations of natural events that did not match my family's interpretations. I recall being shocked to find out that thunder was the result of thermo-expansion of air and not 'God is bowling'. Fortunately, these experiences occurred in a warm, secure, school culture that accepted and accommodated minor differences and encouraged me to develop a science identity.

Unfortunately, these experiences are multiplied and magnified for learners who come from families that do not use the language of the dominant culture or the official language of instruction as they seek to become science literate. Furthermore, the learning environments are not always as understanding and supportive as I enjoyed. International science education reforms focused on science literacy for all students have indirectly increased the importance of the three-language problem (home, school, science) and the need to acquire the language of science as part of the fundamental sense of science literacy. Therefore, it is important that researchers and constructivist-oriented teachers from the dominant culture be aware of and sensitive to the unique issues of each learner in their multicultural classrooms and the range of worldviews and knowledge systems about nature and naturally occurring events.

This special issue of *L1 – Educational Studies in Language and Literature* explores situations where one's traditional knowledge about nature, cultural beliefs, ontological assumptions, and epistemological beliefs are placed in contexts where an academic language of instruction and western science dominate or parallel the home or traditional culture. This brief introductory piece is designed to provide a reference frame for the authors and readers to compare and contrast indigenous knowledge, language, and culture perspectives with the western perspective. There is no implied priority by positioning the western perspective here other than to provide a central reference for the considerations. Some authors will challenge this ideology and values of western science, and the case studies illustrate these between and within cultural frames: border crossing/assimilation, culture restoration/sovereignty, and parallel worlds/two-way border crossings. These insights are provided to help achieve culturally sensitive curricula that encourage explorations and transitions between cultures and discourse communities while respecting the difficulties with acculturation into a science discourse community for some people (Stephens, 2000). Collectively, we have respectfully tried to understand the similarities and differences between traditional knowledge systems about nature and naturally occurring events and western science claims about the same ideas without pressing or ignoring the sociopolitical agenda of some postcolonial and postmodern scholars.

2. BACKGROUND

It is important that the first language (L1), cultural and personal beliefs, ontological assumptions, and epistemological beliefs of students be explicitly considered in multicultural classrooms and in teaching and learning environments where a different language of instruction (L2) and an English-dominated domain of science (L3) are commonplace. Teaching in science classrooms of most countries – with growing immigration, urban cities with multicultural populations, and rural settings with distinct minority groups – requires an understanding of the three-language issue involving students' L1 and related beliefs and values and also the cultural-linguistic transitions to L2 and L3. Honest inquiries of language and science cannot overlook or disregard the cultural values, beliefs, and practices that come with language; and such inquiries will likely provide many insights into the complexities of learning about nature and naturally occurring events in any language. Gee (2004) and Lemke (2004) pointed out both the barriers to and the importance of exploring the learning of science discourses and multiple literacies of science in such situations.

The contemporary definition of science literacy involves the traditional sense of being knowledgeable about science and the fundamental sense of being literate in the discourses of science (Norris & Phillips, 2003). National reforms and curriculum documents for science education implicitly define the traditional sense as the conceptual outcomes involving the big ideas about science that include understandings of the nature of science, scientific inquiry, and technological design, the unifying concepts of science, and the relationships amongst science, technology, society, and environment. The fundamental sense of science literacy involves a set of cognitive and metacognitive abilities, critical thinking, habits of mind, processes, language, and information communication technologies reflected in the science discourse community (Yore & Treagust, 2006). The 'science literacy for all' reforms bring to the surface potential conflicting frames – the nature of science, the roles of language and culture, and the influence of prior knowledge about nature and naturally occurring events (Aikenhead, 2006; Yore, Florence, Pearson, & Weaver, 2006).

2.1 Nature of Western Science

Debates about and considerations of 'whose science' from multicultural, multiethnic, and feminist perspectives have led to the recognition that science is problematic; but these debates have been counter-productive in reaching common ground and resolution – often putting the knowledge systems in competition rather than complementary to one another. Yelling matches between traditional absolutists and postmodernists, postcolonial critiques of science education for multicultural settings, and interpretations of science promoting a relativist view – all opinions are equally valid – have done much to alienate open-minded literacy and science education researchers, advocates for social justice and equity, and scientists from science education by radicalizing the stance, by misrepresenting the nature of real science, and by assigning guilt for past actions. Unfortunately, these debates have moved the consideration solely to the sociopolitical agenda and away from the cognitive agenda, which is based on a sociocultural interpretation of constructivism and the underlying importance of language, culture, and prior knowledge about nature and naturally occurring events common in the international science education reforms.

Both indigenous and western science knowledge systems are valuable and have been useful to the cultures developing them. The U.S. National Science Education Standards (National Research Council, 1996: 201) state:

> Explanations about the natural world based on myths, personal beliefs, religious values, mystical inspiration, superstition, or authority may be personally useful and socially relevant, but they are not science.

This stance appears to place students from cultures with traditional (indigenous knowledge) and religion-based knowledge about nature and naturally occurring events at odds with the science education reform agenda. In a recent study, two well-established scientists in biochemistry and climate sciences were asked if they were aware of traditional knowledge claims about their target interests – sleeping sickness in Africa and Arctic weather systems (Yore et al., 2006). Their responses were very respectful and interesting. Both scientists provided examples of how indigenous knowledge claims helped them focus their research inquiry and data collection. But there are still basic differences between the underlying assumptions and ways of knowing traditional knowledge about nature and western science – causality, explanations, generalizations, argumentation, etc. – that need to be explicitly articulated within the language/science education research community.

Recent court cases in the United States over intelligent design as an alternative scientific interpretation for evolution illustrate how acrimonious the disagreements can become. Aikenhead (2006) provided some general insights into the similarities and differences between western sciences and indigenous sciences. There is some degree of similarity regarding the epistemological practices and beliefs of both of these knowledge systems involving sensory evidence and quality thinking; but the major differences are apparent in the ontological assumptions and requirements of the knowledge systems in terms of the underlying worldview, required explanations, and generalized or place-based knowledge claims. Aikenhead (133) stated,

> Indigenous sciences are guided by the fact that the physical universe is mysterious but can be survived if one uses rational empirical means. Western science is guided by the fact that the physical universe is knowable through rational empirical means.

He outlined six dimensions upon which indigenous and western science differ: social goals, intellectual goals, association with human action, notion of time, validity, and general perspectives. Indigenous sciences are seen as knowledge that supports a way of living for survival and harmony; coexists with and celebrates mystery intimately and subordinately related over human actions; reflects a circular or cyclic conception of time; bases content validity on practical applications over thousands of years of survival; and involves holistic, flexible, intuitive and spiritual wisdom. Western science is seen as knowledge that is valued for its own sake, economic gains, and power over nature; eradicates mystery, magic, and spiritualism in favor of physical causality; disconnects and decouples claims from human action; promotes a rectilinear measure and conception of time; bases content validity on predictive accuracy and utility; and involves a cause-effect and mechanistic explanations.

Metaphysical views of knowledge about nature and naturally occurring events vary along the philosophical continuum of specific ideas about reality, essential qualities, and relations amongst the properties, acceptable explanations, and methods of investigation called ontological assumptions and epistemological beliefs. Ontology deals with the nature and form of reality, relationships between the observer and observed, and the elements and categories used to make claims about reality and to propose explanations about cause. Epistemology deals with how knowledge claims come to be known, the methods and procedures used to study the phenomena, and the fundamental roles and types of evidence used to justify and explain a knowledge claim or event. These assumptions and beliefs vary between the knowledge systems described by Aikenhead (2006), but they vary also within the natural sciences (physics, chemistry, biology and earth and ocean sciences) and between science topics within domains (classical/quantum mechanics, classical biology/ecology, meteorology/climate modeling, etc.). Furthermore, ontology and epistemology influence the traditions, conventions, and practices of knowledge communities: how knowledge is constructed, what data are evidence for a knowledge claim, and what mechanisms are acceptable explanations for an event.

Modern western science is people's attempt to search out, describe, and explain patterns of events occurring in the natural universe (Good, Shymansky, & Yore, 1999). The search is driven by inquiry; limited by human abilities and technology; and guided by hypotheses, observations, measurements, plausible reasoning and creativity, and accepted procedures that try to limit the potential influences of non-target variables by utilizing controls. Although temporary and tentative, the explanations attempt to produce persuasive arguments with coordinated claims, evidence, backings, warrants, counterclaims, and rebuttals and seek to establish physical causality and make generalized claims based on the current evidence and canonical understandings.

This modern naïve realist, evaluativist view of science is positioned between the legendary traditional realist, absolutist view and the postmodern relativist, idealist view (Hand, Prain, & Yore, 2001; Hofer & Pintrich, 1997; Prawat & Floden, 1994; Staver, 1998; Yore, Hand, & Florence, 2004; Ziman, 2000). There are interpretations of science and its underlying ontology and epistemology that cover the continuum between these polar extremes, which are too numerous to discuss here (see Loving, 1998). Haack (2003: 58) used the analogy of a crossword puzzle to describe science:

> It is complex and ramifying, structured – to use the analogy anticipated by Einstein – more like a crossword puzzle than a mathematical proof. A tightly interlocking mesh of reasons (entries) well anchored in experience (clues) can be a very strong indication of the truth of a claim or theory that is partly why 'scientific evidence' has acquired its honorific use. But where experiential anchoring is iffy, or where background beliefs are fragile or pull in different directions, there will be ambiguity and the potential to mislead.

This analogy becomes even more meaningful if you imagine picking up a crossword puzzle from the seat pocket of an airplane or the recycle bin at the train station to discover a partially finished puzzle with word solutions in several languages and some completed in ink by a very confident person. The crossword puzzle analogy illustrates doing science as inquiry, using evidence (clues, available space, etc.) and canonical knowledge (completed solutions, give away relations between clue and solution, etc.) leading to further solutions as a network of ideas with commonalities and to public criticism of the products. Haack (93-94) continued:

> Some entries were completed hundreds of years ago by scientists long dead, some only last week. At some times and places, … there is pressure to fill in certain entries this way rather than that, or to get going on this completely blank part of the puzzle rather than working on easier, partially filled-in parts – or not to work on certain parts of the puzzle at all. Rival teams squabble over some entries, … [while other] teams cooperate to devise a procedure to churn out all the anagrams of this chapter-long clue or a device to magnify that unreadable tiny one, or call to teams working on other parts of the puzzle to see if they already have something that could be adapted.

The crossword puzzle analogy illustrates the interplay between scientists, scientific enterprise, and society. Alternative interpretations of clues in isolated solution spaces with few connections to other problem space do not impede progress, while solutions with numerous intersections can impede or mislead further solutions. Likewise, science has well-established knowledge that is unlikely to change and more tentative claims that are susceptible to change. Science depends upon the scientific and sociopolitical enterprises to fund research, judge value, and attract new scientists.

Duschl (2000) pointed out that general claims about the nature of science and scientific attributes cannot be based on a single scientist or event but rather on the collective histories, traditions, and conventions of the scientific enterprise, events, and scientists. Western interpretation of science grew out of and was heavily influenced by the cultural traditions, religious beliefs, and languages (especially Latin, Greek, English, German, and French) of people in Europe. Much research and writing has been devoted to espousing the unique ontological and epistemological features of science as contrasted to pseudoscience, religion, and other disciplines. Cobern and Loving (2001: 58-60) outlined the critical attributes of science – factoring out the human attributes of scientists – as:

1) Science is a naturalistic, material exploratory system used to account for natural phenomena that ideally must be objectively and empirically testable.
2) The Standard Account of science (Western Science) is grounded in metaphysical commitments about the way the world 'really is'.

This modern view sets science in a scientific worldview in contrast to a traditional worldview and differentiates science from technology. Technology is not an applied science but rather people's attempts to address or alleviate issues of human need by adapting the environment utilizing design and trial-and-error approaches (Yore, Hand, & Florence, 2004). History of technology has examples of inventors producing innovations in advance of the scientific explanation. Frequently, the debates about science have not kept the differences between science and technology clear and, by doing so, confound the issues regarding the need for western science to move toward explanations utilizing physical causality rather than magic, mysticism, and spiritualism.

2.2 Roles of Language in Science and Science Education

The history of science illustrates the interacting sociocultural and linguistic dimensions with international collaboration and competition among scientists, the common use of inquiry, argument, mathematical operations and models, and the importance of visual, spoken, and written communications to construct, describe, defend, and present ideas (Yore et al., 2006). Language does more than report inquiries, data, and knowledge claims; it shapes conceptualizations and understandings (Florence & Yore, 2004; Yore, 2004). Scientific language, especially print-based language and symbol systems, is a problem-solving tool that utilizes unique patterns of argumentation and form-function (genre) to explore relationships among variables and causality among natural elements and events. The modern view of science recognizes the interactive and constructive role of language in doing science, constructing science claims, and reporting the results of scientific inquiries. Language is an essential cognitive technology, and it is an integral part of science and science literacy. Language is a means of doing science and to constructing science understandings; language is also an end, a fundamental goal of science literacy, in that it is used to communicate about inquiries, procedures, and science understandings to other people so that they can make informed decisions and take informed actions.

> The language arts (talking, listening, interpreting, representing, reading, and writing) are important abilities for scientists as they seek research funds, make sense of their experiences, and present their research questions, experimental procedures, knowledge claims, and evidence to inform and persuade other scientists and laypeople about their work. Each of these functional roles places different demands on the form and use of language by scientists. (Yore et al., 2006: 113)

Language serves parallel functions for constructivist-oriented science learning by facilitating negotiations and reflections about learner-developed and metacognitive-managed knowledge claims constructed from a collection of sensory experiences, conversations, print information sources, and prior knowledge in an interactive sociocultural context (Yore & Treagust, 2006).

Words, symbols, and terms are labels for ideas, mental images, experiences, actions, etc. that may have no direct association with the underlying idea and may have different meanings than the same label in another discourse community, discipline, or social context. Correct spelling of the word does not ensure conceptual understanding of the signalled idea. *Amoeba* has no clues to the unique microorganism without the learned associations to the microscope experience dealing with shape, parts, and movement of the organism. Some words can provide clues if the underlying root words are understood – *carbohydrates:* carbon and water re-combine to hydrates of carbon. Other words that are fundamental to science are used differently in different discourse communities. *Theory* stimulates unique differences in a fundamental Christian community than in a developmental biology community where it is no less tentative than a *law* but brings an integrative and explanatory power with its use. Some cultures and languages do not have words in their lexicon/register – or they may have unique interpretations – for some critical ideas in science, such as argument, etc.

Oral language is necessary but not sufficient to do modern science that requires persuasive arguments and explanations (Norris & Phillips, 2003). Talking and listening science provides a time-efficient, responsive method to share ideas; but it is unlikely that the oral dimension alone will provide the mechanism and permanence to establish the connections amongst and explanation of data, canonical knowledge, evidence, and claims and an effective medium for reflection and critical analysis (Bazerman, 1988; Yore, Bisanz, & Hand, 2003). Scientists use writing to create permanent records to establish their data, thinking, and direction for discoveries, proprietorship of intellectual properties, and as documented sources for reflection, analysis, and evaluation (Chaopricha, 1997). Print-based language skills are critical attributes for scientists to become full members of their scientific discourse communities (Florence & Yore, 2004). The research literature indicates that argument and scientific reports are dominant genre, scientists read purposefully the same journals in which they publish, they have well-defined audiences for their writing that vary from a few specialists working in the same problem space to thousands of colleagues on general issues of concern, and they believe the write-review-revise procedure of peer-review improves the quality of the science as well as the quality of the writing (Bazerman, 1988; Chaopricha, 1997; Dunbar, 2000; Florence & Yore; Yore et al., 2006; Yore, Hand, & Florence, 2004; Yore, Hand, & Prain, 2002). Yore et al. (2006: 115) stated:

> Scientists describe writing any lengthy piece of text as a coordinated effort among authors, research associates, and smaller related writing tasks spread over several months or a year. Scientists consult other scientists, databases, and related texts while writing to access expert opinions, additional data, and other established claims. On some occasions, scientists return to the laboratory to verify data and collect additional evidence to address weaknesses in their arguments detected during the writing-review-revision process.

Contemporary science research is a mix of people and talents that may be located together or at a distance connected by information communication technologies. Expertise is distributed by function and responsibility across the members of the research group with various members taking the leadership role at different times (Florence & Yore).

2.3 Roles of Culture in Science Education

Life-world knowledge, including science, is the product of a particular human culture; and these ideas are filtered and influenced by the central beliefs of the culture and lived experiences of the knower. Ziman (2000: 302) stated:

> But a great part of it is shared only with the members of a particular human group. To belong to a culture requires active knowledge of a variety of social entities, such as personal roles, representational codes, symbolic objects, organized collectives and other public institutions characteristic of that culture. Respectful recognition of significantly different human cultures … is a prerequisite for any general understanding of those aspects of the life-world studied in the human sciences.

Many people carry membership in several cultures as multicultural hybrids; and these cultural components influence their identities, beliefs, and actions. The complex and highly personal systems of general and specific beliefs – practical maxims, legal principles, religious teachings, cultural folklore, and even science theories – provide guidance and comfort in the face of the unexpected or misunderstood events. Both science (and scientists) and technology (and engineers) represent cultures with a distinct system of beliefs, values, traditions, and conventions; and membership in these cultures is acquired like the cultural attributes acquired from parents, grandparents, and community (Florence & Yore, 2004). Unprecedented material development of some cultures is associated with those cultures' advancements in the physical and biological sciences and their organization for the invention, production, and distribution of technologies and technical services.

Worldviews that involve unique assumptions about the philosophy of knowledge, ways of knowing, and cultural organization, traditions, conventions, and practices provide a framework for considering cultural influences (Cobern, 1991). Two worldviews – traditional and scientific – maintain different ontological assumptions of causality, epistemological beliefs about knowing, and desired generalization of knowledge claims. These similarities and differences will be situated and addressed in the cultural context of several of the case studies that follow. Frequently, conflicts between worldviews involve religious beliefs or deeply held moral values and social, political, or economic issues and do not recognize the differences in the ontology and epistemology of science and other personal belief systems (Haack, 2003).

2.3.1 Cultures in Conflict

Conflict between cultures founded on these worldviews exists between science and religion. The ongoing debates (Scope Trial, 1925–Dower, PA, School Board, 2005) in the United States about evolution and divine creation or intelligent design illustrate the lack of recognition or acceptance of the fundamental difference in the philosophical foundations of science and religions (Colburn & Henriques, 2006). Yore and Knopp (2001) pointed out that the public debates between people illustrate the misunderstanding of each other's position in the misuse of terminology (theory as simple speculation, etc.) and view of the discipline (science as an absolute or totally uncertain body of knowledge, etc.). This difference between science and religion involves not only the development of humans but also includes the age of the earth, the origin of the universe, and the acceptance that people are members of the animal kingdom and not superior to other species in the environment. The conflict manifests itself in political arenas, public policies, and school curricula debates, which have put some of the most vulnerable teachers at risk (Singham, 2000). The winner-takes-all sides – religion trumps science and science trumps religion – in these debates do not wish to cross borders and recognize and respect opposing perspectives on the central issues of evolution, cosmology, and ecology (Colburn & Henriques; Yore & Knopp). Fundamental Christians have anchored their position on the literal interpretation of the Bible and believe that it "is through inerrant scripture or religious tradition that we come to know the ultimate truth about nature" as well as the moral and ethical principles for living a 'good' life; the other side believes that it "is through the methods of science that we learn the ultimate truth about nature" (Nord: 1999: 29). Furthermore, this side believes that intelligent design has been presented by some religious people as a ruse to weaken or confound the debate between the extremes of science and religion (Good, 2005).

2.3.2 Parallel Cultures with Two-Way Border Crossing

But many science-oriented, religious people (including a large number of scientists) accept the parallel courses of science – focused on searching, describing, and explaining some events using physical causality – and of religion – focused on why and how to live a life in concert with a set of moral principles based on faith alone. They appear to view science and religion as different ways of knowing (epistemology) involving different fundamental structures and basics components of the knowledge domain (ontology). Haack (2003: 267) stated:

> Religion, unlike science, is not primarily a kind of inquiry, but a body of belief – 'creed' is the word that comes to mind. At the core of religious world-view, as I understand it, is the idea that a purposeful spiritual being brought the universe into existence, and gave human beings a very special place. This spiritual being is concerned about how we humans behave and what we believe, and can be influenced by our prayers and rituals.

Religions, unlike science, focus on absolute truths and supernatural explanations using authority from revealed text and faith (Yore & Knopp, 2001). On occasion, these parallel worlds of science and religion apply to intersecting issues involving society and environment.

> The major Western religions – Judaism, Christianity, and Islam – have made sense of reality not in terms of universal causal laws but in terms of narratives. Events become intelligible not because they are lawlike but because they fit into a narrative (as miracles might). Theologians discern patterns of meaning and purpose in history and nature that they understand in terms of a divine causality in the world. (Nord, 1999: 29)

It is precisely how literal and rigid these interpretations of scripture and to what degree divine causality are ascribed that defines the interface of science and religion. Pope John Paul II (1996) affirmed that the theory of evolution had strong scientific support and did not contradict the teaching of the Roman Catholic Church as long as it did not impose a scientific causality for people's souls. This parallel-cultures approach to religion and science attempts to achieve a common respect and sensitivity to the interpretation of scientific inquiries and religious narratives that allows people to move back and forth between the two cultures in a two-way border crossing. This approach might have led to the proposition of intelligent design, which encounters resistance from scientists in the degree and frequency of God's intervention in the evolutionary process (see Colburn & Henriques, 2006, for further discussion and classroom suggestions). Some scientists will accept the initial intervention by God at the beginning of time but reject any further intervention by God. Nord (29) stated, "neither [science nor religion] can ignore the other, and neither automatically trumps the other. Because science and religion are each competent to illuminate aspects of the same reality, a fully adequate picture or reality must draw on – and integrate –

both." More importantly, both are part of some people's beliefs and values that they bring to the public debate about science, technology, society, and environment issues and learning about science and technology.

Religion and science are not the only conflicting or parallel cultures that face language, literacy, and science education researchers and teachers. History presents an image of science as being a male-oriented culture replete with male heroes and male-oriented terminology. Although males likely dominated early history of science, nothing in the nature of science is fundamentally male; and barriers to equity appear to be social, political, and economic. Morse (1995: 11) stated:

> To suggest that women have played a role in scientific inquiry that in any way approaches that of men's role is revisionism in its most naïve and damaging form, which serves not to convince of the value of women's activities, but to diminish the possibilities from women's future contributions.

Feminists and social justice efforts have done much to reject science as an exclusive male activity and to make the scientific enterprise more welcoming and inviting to women and a broad array of underrepresented and underserved groups of people. Unfortunately, these efforts have not been equally successful across all science and technology domains. Equality has been achieved in many of the hybrid sciences, biosciences, and computer sciences; but women are still significantly underrepresented and underserved in engineering, mathematics, and physical sciences.

3. CLOSING REMARKS

Students' culture, lived experiences, and vernacular or home language are foundations of academic learning; and they must be recognized, respected, and utilized to anchor abstract concepts (Gee, 2004). Not recognizing students' cultural language, beliefs, and values in teaching science will disenfranchise their culture (lived experiences, home, family, community) from the school and academic culture. Furthermore, some students cannot identify their cultural or linguistic contribution to the science register or knowledge stores (Dlodlo, 1999; Gray, 1999). Such lack of connection with the discipline or the institution potentially leads to identity problems; Brown (2006: 96) found that Grade 9 and 10 students "experienced relative ease in appropriating the epistemic and cultural behaviours of science, whereas they expressed a great deal of difficulty in appropriating the discursive practices of science."

Conceptual change and constructivist teaching assumed that science learning is best understood as students' engagement with concepts and methods, where students' own ideas or prior knowledge affect their engagement, producing diverse learning opportunities. This perspective tended to emphasize science learning as mainly the challenge of existing prior knowledge and the acquisition of conceptual knowledge (assimilation of new ideas into an existing conceptual network or restructuring the conceptual network to accommodate discrepant ideas) and downplayed cultural differences in learners and the influence of different cultural contexts on learning. However, there has been a growing awareness of differences amongst learners' identities, values, and communication resources for learning that affect their interest and progress in the subject (Allen & Crawley, 1998; Brown, 2006; Kawagley, Norris-Tull, & Norris-Tull, 1998; Sutherland, 2002).

Aikenhead (2003: 53) suggested that even many mainstream students view science as a "foreign culture that does not engage their self-identities" and lacking cultural relevance and that students are likely to respond more favorably to authentic inquiries that connect to their cultures, lives, beliefs, and values. Alvermann (2002) and Gee (2003) asserted that students were willing to engage at length and with considerable success in computer-mediated literacies outside the classroom where they perceived a personal reward for effort, in terms of affiliation with a meaningful subgroup, mastery of a field, or in support of a positive sense of self-identity. These researchers suggested that these activities provide insights into the conditions and identify resources that might more successfully connect science learning with diverse students and their cultures, knowledge, and lived experiences.

The nature of science debates and the science and religion debates have oscillated between the extremes, setting them in competition with each other, and have done little to articulate a complementary framework that would inform science education. Ziman (2000) suggested that many people in the 'science wars' are talking about the legendary images of science that have not existed for decades – rather than real science practiced by today's scientists. On several occasions, these debates intermix science as inquiry and technology as design or do not separate their socio-political agenda from the ontological and epistemological dimensions. Ontology of western science deals with fundamental elements and foci – the general view of reality and the specific features of objects, events, and processes: matter, elements, atoms, length, mass, time, electrical charge, rate, cycles, etc. Epistemology of western science involves the characteristic ways scientists know about the fundamental issues in their discipline involving inquiry, collection of data, quality of evidence, etc.

Haack's (2003) analogy of a crossword puzzle cooperatively solved with other people, both current and historical, anchors three essential, inter-related issues:

- *Language of Science.* She points out how metaphors, analogies, and models are used as tools to heighten and focus imagination and that basic science prose is (a) argument – designed to link evidence, claims, established science, and warrants and (b) rhetorical – to persuade others that the argument is justified by the quality and quantity of evidence and the rational thinking involved.
- *Inquiry and Evidence.* Her perspective focuses on the quality and quantity of evidence (relevance, sufficiency, reasonableness, supportiveness) and how it warrants claims (degree of credence) as essential characteristics of critical stance on science and on scientific claims.
- *Views of Science.* Her descriptions of 'good' science and her questioning of the 'old differential' and 'new cynic' perspectives lead toward a middle-of-the-road view of science that emphasizes the ontological beliefs and epistemological assumptions.

Western science is frequently described as inquiry in the science education reform documents, but it could just as easily be described as argument. Full participation in the western scientific cultures and discourse communities requires proficiency in and acceptance of argumentation as the means of knowledge construction and sharing.

> The notion that argument was something central to science. … Yet ironically, the work undertaken by cognitive psychologists has shown that adolescents have limited capabilities at constructing warrants that relate data to explanatory theories, and that the study of school science appears to do little to improve such reasoning" (Yore, Hand, Goldman et al., 2004: 348).

Argumentation may be a discrepant linguistic approach for some cultures, societies, and genders. The 'in your face' approach of presenting a knowledge claim over alternative claims with supportive evidence justified by warrants based on established, canonical backings may not be a common custom for some people. The traditional scientific pattern of argument is perceived by some to be confrontational, disempowering, and discrepant to a softer mythological pattern of description and explanation associated with a traditional worldview. But argumentation is a fundamental and traditional convention for doing and reporting research in western science discourse communities.

Language is an intimate, inseparable part of doing and learning science – it influences the science and does not simply report the processes, procedures, and results of scientific inquiry or simply represent the conceptual network of canonical science. Language is not value free – cultural beliefs and values are inherent in every language. Furthermore, all children bring a well-developed, vernacular dialect or home language other than standard English to school that provides them identity and association with families, homes, and communities (Gee, 2004). Not recognizing non-standard forms of English and native languages can be both a barrier to acculturating these students into school environments with mutual respect and an oversight to rich prior experiences that can support science learning.

This special issue explores language, culture, and traditional knowledge system as influences on science literacy for all students; it is a first step to documenting such events for French Canadians in the eastern provinces, Spanish-speaking people in rural Mexico, African people in Southern Africa, majority and minority people in Taiwan, Canadian First Nations people, and Maori people of New Zealand – who use their L1 at home, but are operating in an L2 (most often English or a standard dialect of L1) in their science instruction, and moving toward an L3 (science language). Each author team addressed a similar set of focus questions regarding:

- Cultural beliefs about nature and naturally occurring events.
- Ontological and epistemological assumptions about causality and nature.
- Linguistic practices and features related to crossing borders between their home, school, and science languages and between traditional knowledge about nature and western science.

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