CULTURE, LANGUAGE, KNOWLEDGE ABOUT NATURE AND NATURALLY OCCURRING EVENTS, AND SCIENCE LITERACY FOR ALL: *SHE SAYS, HE SAYS, THEY SAY*

PAULINE W.U. CHINN*, BRIAN HAND**
& LARRY D. YORE***

**University of Hawai'i at Mānoa, Hawai'i, **University of Iowa, Iowa (USA)*
****University of Victoria, British Columbia (Canada)*

Abstract. Pauline Chinn and Brian Hand, both well-established science educators interested in the role that language plays in doing and learning science but with distinctly different stances, provide a glimpse into an ongoing conversation and deliberation over 18 months about what does it mean to come to know in science and how does this concept of science translate into pedagogical practices. Larry Yore moderates and promotes these conversations and deliberations to help identify intersections and shared understandings and to contrast areas of differences and disagreements. These professional reflections on their critical thinking and fundamental assumptions about culture, language, and knowledge about nature and naturally occurring events demonstrate the necessary and essential processes required to move the science literacy for all agenda forward. They share their fundamental stances and perspective about sociopolitical issues, postcolonial stances, science, and schooling without being sidetracked from their purpose to inform and increase awareness about the critical issues in science literacy for all. Their conversations and insights may well be equally informative and empowering to students from majority and minority cultures, since all learners appear to be second language learners when it comes to science language, linguistic devices, and discourse patterns.
Keywords: effective curriculum and instruction, pedagogy, science literacy for all, ways of knowing

Dutch
Samenvatting [Translated by Tanja Janssen].
Pauline Chinn en Brian Hand, beiden gespecialiseerd in het natuurwetenschappelijk onderwijs en geïnteresseerd in de rol die taal daarbij speelt (zij het dat zij daarbij andere accenten leggen), geven een kijkje in 18 maanden durende beraadslagingen over wat het betekent om ingewijd te worden in de natuurwetenschappen en hoe dit concept van natuurwetenschappen zich laat vertalen in pedagogische praktijken. Larry Yore treedt op als gespreksleider bij deze gesprekken en beraadslagingen en helpt verbanden, ge-

Chinn, P.W.U., Hand, B., & Yore, L.D. (2008). Culture, Language, Knowledge about Nature and Naturally Occurring Events, and Science Literacy for All: She Says, He Says, They Say
L1 – Educational Studies in Language and Literature, 8*(1), p. 149-171.*

Correspondence concerning this article should be directed to Pauline W.U. Chinn, University of Hawai'i at Mānoa, Everly Hall 225, 1776 University Avenue, Honolulu, Hawai'i 96822, USA, Tel: 808.956.4411, Fax: 808.956.9905. Electronic mail may be sent to chinn@hawaii.edu.

deelde opvattingen en gebieden waarop er meningsverschillen zijn vast te stellen en te verhelderen. Deze beroepsmatige reflecties op hun kritisch denken en fundamentele vooronderstellingen over cultuur, taal en natuurwetenschappelijke kennis brengen de noodzakelijke, essentiële processen aan het licht die nodig zijn om de agenda van ‘science literacy for all’ te dienen. Zij wisselen hun fundamentele standpunten en perspectieven met elkaar uit over sociaal-politieke, post-koloniale kwesties, over natuurwetenschap en scholing zonder hun doel uit het oog te verliezen: informatie geven over en bewust maken van de belangrijke kwesties in ‘science literacy for all’. Hun gesprekken en inzichten kunnen even informatief zijn voor leerlingen uit meerderheids- en minderheidsculturen, aangezien alle leerlingen tweede-taal-leerders zijn wanneer het gaat om de taal van de (natuur)wetenschap, talige middelen en patronen van geschreven en mondelinge taal.

French

Résumé [Translated by Laurence Pasa]
Pauline Chinn et Brian Hand, deux enseignants des sciences expérimentés, tout deux intéressés par le rôle du langage dans l’apprentissage des sciences mais à partir de positions très différentes, fournissent un aperçu d’un débat de 18 mois au sujet de ce que signifie apprendre en sciences et comment ce concept de science se traduit en pratiques pédagogiques. Larry Jadis modère et stimule la discussion en permettant d’identifier des croisements et des points de vue communs, tout en soulignant les différences et les désaccords. Ces réflexions professionnelles et critiques sur les présupposés fondamentaux relatifs à la culture, à la langue, et aux connaissances de la nature et des phénomènes naturels illustrent les processus nécessaires et essentiels au progrès de l’enseignement des sciences. Les auteurs partagent leurs points de vue et leurs perspectives au sujet des issues sociopolitiques, des positions postcoloniales, de la science, et de la scolarisation, tout en ne perdant pas de vue la visée d’information et de prise de conscience des questions cruciales posées à un enseignement-apprentissage des sciences destiné au plus grand nombre. Leurs échanges et leurs réflexions peuvent être également intéressants et valorisants pour les élèves issus des cultures majoritaires et minoritaires, puisque tous les élèves s’avèrent confrontés à un apprentissage en L2 lorsqu’ils abordent le langage scientifique, les procédés linguistiques et les modèles de discours.
Mots-clés: programme d’enseignement efficaces, pédagogie, enseignement-apprentissage des sciences pour tous, manières d’apprendre.

Italian

[Translated by Manuela Delfino].
Pauline Chinn e Brian Hand, entrambi affermati docenti di scienze interessati al ruolo che la lingua gioca nel fare e nell’apprendere le scienze, ma con posizioni ben distinte, forniscono uno spaccato su un dibattito ancora in atto e una riflessione svolta nell’arco di 18 mesi su ciò che significa giungere a conoscere nelle scienze, e come questo concetto di scienza si traduca in pratiche pedagogiche. Larry Yore modera e promuove il dibattito e le riflessioni per aiutare a identificare le intersezioni e le interpretazioni condivise e per contrapporre le aree di divergenza e i disaccordi. Queste riflessioni condotte da professionisti sul loro pensiero critico e sugli assunti di base in merito alla cultura, alla lingua e alla conoscenza della natura e degli eventi che accadono in natura sono una prova dei processi necessari ed essenziali per far avanzare il progetto di un’alfabetizzazione scientifica per tutti. Gli autori condividono le posizioni e le prospettive di base in merito ai temi sociopolitici, alle posizioni postcolonialiste e alla scuola, senza essere distratti dal loro scopo di informare e accresce la consapevolezza sulle questioni problematiche in un‘alfabetizzazione scientifica per tutti. Il dibattito e le intuizioni da loro proposte possono essere ugualmente istruttive e rappresentare uno strumento di emancipazione per gli studenti provenienti da culture di maggioranza o di minoranza, dal momento che tutti gli studenti sembrano essere discenti di una seconda lingua, quando si trovano ad apprendere la lingua, gli strumenti linguistici e le strutture discorsive delle scienze.
Parole chiave: curriculum e didattica efficaci, pedagogia, alfabetizzazione scientifica per tutti, modi del conoscere

Polish

Streszczenie [Translated by Elzbiéta Awramiuk]
Pauline Chinn i Brian Hand, uznani nauczyciele nauk ścisłych zainteresowani rolą języka w tworzeniu nauki i zdobywaniu wiedzy z dziedziny nauk ścisłych, choć zajmujący zupełnie różne stanowiska, dają wgląd w toczącą się od ponad 18 miesięcy dyskusję nad tym, co to znaczy dowiedzieć się czegoś w nauce i jak pewne pojęcie nauki przełożyć na praktykę pedagogiczną. Larry Yore prowadzi debatę i dba, aby te

dyskusje i rozważania pomogły zidentyfikować punkty przecięcia i wspólne przekonania oraz skontrastować obszary różnic i niezgodności. Te profesjonalne refleksje o ich krytycznym myśleniu i fundamentalnych założeniach dotyczących kultury, języka i wiedzy przyrodniczej demonstrują istotne procesy, konieczne aby osiągnąć postęp przy tworzeniu programów nauczania przedmiotów ścisłych. Autorzy dzielą swe fundamentalne stanowiska i perspektywy dotyczące zagadnień socjopolitycznych, postkolonialnych, nauki i szkoły mając na celu informowanie i budowanie świadomości na temat najważniejszych zagadnień w powszechnym nauczaniu przedmiotów ścisłych. Ich rozmowy i poglądy mogą być informatywne i pożyteczne dla studentów z dominujących i mniejszościowych kultur w tym sensie, że gdy chodzi o język naukowy, językowe środki wyrazu i dyskursywne wzorce to wszyscy uczący się mogą być traktowani jako uczący się w drugim języku.
Słowa-klucze: efektywne nauczanie i program, pedagogika, podstawy nauki dla wszystkich, sposoby poznawania

Portuguese

Resumo [Translated by Paulo Feytor Pinto]
Pauline Chinn e Brian Hand, reconhecidos educadores em ciência interessados no papel da língua na produção e aprendizagem científica, mas com diferentes perspectivas, dão-nos uma rápida visão de um debate em curso ao longo dos últimos 18 meses acerca do significado do conhecimento científico e de como este conceito de ciência se traduz em práticas pedagógicas. Larry Yore promove e modera este debate tendo em vista a identificação de intercepções e de entendimentos partilhados e o destacar das áreas de desacordo e divergência. Estas reflexões profissionais sobre o pensamento crítico e as concepções fundamentais acerca da cultura e da língua, e sobre o conhecimento da natureza e de fenómenos naturais evidenciam os processos essenciais e necessários para avançar com uma agenda da literacia científica para todos. Eles partilham as suas abordagens e perspectivas acerca de questões sociopolíticas, pós-coloniais, científicas e educativas sem se desviarem do seu propósito de informar e de aumentar a consciência acerca das questões críticas da literacia científica para todos. As suas conversas e visões podem ser igualmente informativas e capacitadoras, para estudantes tanto de culturas maioritárias como minoritárias, uma vez que todos os aprendentes parecem ser aprendentes de uma língua segunda sempre que se trata de linguagem científica, de mecanismos linguísticos e de padrões discursivos em ciência.
Palavras-chave: instrução e currículo efectivo, pedagogia, literacia científica para todos, modos de conhecimento

Spanish

Resumen [Translated by Alejandro Arrington from Benemérita Escuela Normal Veracruzana, Mexico]
Lengua, cultura, conocimiento de la naturaleza y los eventos naturales, y acercamiento al estudio de las ciencias para todos: *ella dice, el dice, ellos dicen*
Pauline Chinn y Brian Hand, educadores en el área de Ciencias interesados en el rol que juega el lenguaje en la práctica y el aprendizaje de las Ciencias pero situados en distintas posturas, proveen una mirada a una conversación y deliberación que se ha estado llevando a cabo a lo largo de 18 meses acerca de lo que significa llegar al conocimiento en las Ciencias y cómo este concepto de ciencia se traduce en prácticas pedagógicas. Larry Yore modera y promueve dichas conversaciones y deliberaciones para ayudar a identificar intersecciones y compartir entendimientos, y contrastar áreas donde existen diferencias y desacuerdos. Estas reflexiones profesionales sobre el pensamiento crítico y suposiciones fundamentales sobre cultura, lenguaje, conocimiento sobre la naturaleza y los eventos naturales demuestran los procesos necesarios y esenciales que se requieren para lograr un avance en la agenda de acercamiento al estudio de las Ciencias para todos. Ellos comparten posturas y perspectivas fundamentales acerca de asuntos sociopolíticos, posturas postcoloniales, Ciencias, y educación, sin abandonar el propósito de informar e incrementar conciencia sobre asuntos de importancia para el acercamiento al estudio de las Ciencias para todos. Sus conversaciones y entendimientos pueden ser informativos y al mismo tiempo brindar potestad de acción a los estudiantes de las culturas mayoritarias y minoritarias, ya que todos los estudiantes operan como estudiantes de una segunda lengua cuando se trata del lenguaje de las Ciencias, los mecanismos lingüísticos, y los patrones discursivos.
Palabras clave: currículo e instrucción efectivos, pedagogía, acercamiento al estudio de las Ciencias para todos, aproximaciones a los procesos del conocimiento

1. INTRODUCTION

The series of papers presented in this special issue begin to address the questions: *What is science literacy for all?* and *How appropriate is the pedagogy being used in the classrooms across these multiple settings?* Importantly, the connections between students' home situations, worldviews, and how various groups construct knowledge are critical in promoting science literacy in both the fundamental and derived senses. These articles and this synthesis have struggled with what it means to be literate from various cultural and linguistic perspectives in the discourses of and dealing with knowledge systems about nature and naturally occurring events and with the knowledge and understanding that such systems establish, value, and use. In addressing the issue of culture, language, and education, the authors come from different backgrounds and perspectives.

Here, as Aikenhead (2006) has done, Pauline and Brian, with Larry as a moderator, have agreed to provide a thoughtful point-counterpoint discussion of the nature of science and technology to alert literacy researchers to the basic epistemological assumptions, ontological foundations, goals, beliefs, and values inherent in different worldviews that are embraced by different cultures and embedded in indigenous knowledge and western knowledge about nature and naturally occurring events. However, in the final section on learning and instruction, Pauline and Brian have greater convergence in their perspectives about science literacy instruction for all that focuses on constructivism. Their interpretations of constructivist approaches have some common features and some differences but center around interactive-constructivist or social constructivist pedagogies. Finally, in the closing remarks, the three authors point out some promising avenues for research and instructional innovations.

We have framed the paper around a number of dialogical interchanges (*she says – he says – they say* conversations over 18 months) to provide the reader with an opportunity to understand how the issues being raised are complex and need to be discussed from multiple viewpoints. In preparing this paper, we spent time discussing the theoretical frame from which to build the structure of the paper. In doing so, we decided that there are two major issues that need to be dealt with in the context of this special issue:

1) What does it mean to come to know in science?
2) How does this translate into pedagogical practices?

2. WHAT DOES IT MEAN TO COME TO KNOW IN SCIENCE?

Aikenhead (2006: 107-108) stated that "Culture-based clashes occur in science classrooms for students whose worldviews and cultures (including their home language) differ from those of Western science conveyed by school science. … Discordant worldviews create an incompatibility between … [the] students' identities." Here he is concerned about the students' personal identities and the students' views of western science, school science, science teachers, and the kind of person they would need to become to engage in and embrace science. These clashes increase in frequency and severity as the students' home culture and language differ from the dominant English western science discourse culture. Aikenhead (113) acknowledged the similarities and differences between western and indigenous science: "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.*" These knowledge systems involve observations and data collected by experimental and field studies and claims, descriptions and explanations based on rational ways of knowing within different culture-laden rationalities. The indigenous and western systems differ in:

- *social goals:* knowledge (ways of living) for survival and harmony with nature versus knowledge for its own sake, for economic gain, and for power over nature.
- *intellectual goals:* coexistence with the mystery of nature by celebrating mystery versus eradication of mystery by describing and explaining nature in ways familiar to Western scientists.
- *association with human actions:* intimately and subjectively related versus formally and objectively decontextualized from normative prescriptions of human actions.
- *notion of time:* circular versus rectilinear.
- *validity:* content validity as evidenced by tens of thousands of years of survival based on that content versus predictive validity that is the cornerstone of Western science.
- *general perspectives:* holistic, accommodating, intuitive, spiritual *wisdom* versus reductionistic, manipulative, mechanistic *explanations*. (Aikenhead, 113)

The similarities and differences need to be known and considered during deliberations to develop culturally sensitive and respectful experiences about nature and naturally occurring events that might promote contemporary science literacy and provide opportunities for *all students* to achieve this goal. It is these deliberations about what it involves to know about nature and naturally occurring events that Pauline and Brian will share. Larry, as moderator, has provided where necessary brief introductory and closing frames to their deliberations.

2.1 Within and Between Views of Knowledge about Nature and Naturally Occurring Events

Similarities and differences are not apparent until two or more examples are known and a compare-contrast analysis is applied to the available examples. The analysis will lead to descriptions of attributes that are shared and common between or amongst the examples and that are not shared, distinctive to some examples but not others. This process does not need to involve value judgments. The 'science wars' were all about judgments and some other sociopolitical agendas. Brian and Pauline's deliberations in developing this article tried to isolate the sociopolitical agendas and to avoid value judgments.

Brian: In discussing this issue, one immediately begins to run into arguments about trying to define science. Clearly, Yore (2008) introduces a perspective about western science and the discrepancies between science and religion in the opening paper. I believe there is a need to make a distinction between *within-culture* and *between-culture* views of science. By within-culture, I am referring to people who remain within a single culture and have a particular way of knowing and believing about science versus a between-culture view where people constantly move between their own culture and the dominant cultures of practice – in this case, the dominant culture being western modern science. Note here that I use the descriptors *western* and *modern* to differentiate between sciences practiced in the twenty-first century from the legendary science of the 1600s (Ziman, 2000). A within-culture view enables the adoption of particular views of nature that are acceptable to those within the culture. Thus, within an aboriginal culture, there is traditional ecological knowledge and wisdom or indigenous knowledge. However, in a between-culture view, a different interpretation of the same knowledge has developed and is used across multiple settings. In this case, the dominant view (western science) is seen as a form of knowledge that is used across multiple cultures and is based on a particular set of practices that are different from a strictly within-culture view. One could argue that there exist two or more forms of knowledge about a particular phenomenon that are parallel in a between-culture view – indigenous knowledge and science knowledge. For Aikenhead (2006), it is the ontological base for different cultures that separate these forms of knowledge. Indigenous knowledge has an ontological base of myth and mysticism, while western modern science knowledge is based on knowable physical causality.

Pauline: I would like to present a more complex picture than simply bipolar worldviews; this picture is less clear-cut in that it involves a hybrid worldview of mixed ontological assumptions leading to multisciences. I agree that indigenous knowledge – whether European, Asian, or Oceanic – has an ontological base in myth, metaphor, and mysticism. Western modern science has roots here as well, as in the 'tree of life' metaphor. We must also recognize that areas of indigenous knowledge are based on knowable physical causality. I recently accompanied a Greek friend with a graduate degree in physics to his remote, northern village in the Zagori. He took me to a cool, thickly forested area still called the 'lungs of the forest' where animals are not allowed to graze or people allowed to cut trees. Generations of living sustainably in the mountains produced knowledge and personal connections to the land leading to an anthropomorphic metaphor and norms protecting the village's precious water supply. This short story suggests the perspective of coming to know in science presented by papers in this issue: moving from home culture and language (L-1) into school culture and language (L-2) into the culture and language of school science (L-3) requires students to move between cultures, even if L-1, L-2, and L-3 are the same basic language. Similar stories are illustrated by folklore worldwide about weather, agriculture, and navigation. Some folklore is based on fact and physical causality and others on fancy and mysticism, but all are metaphorical.

Scientists and science educators often do not recognize the fundamentally social and linguistic basis of coming to know as a member of a scientific subculture because western science historically omitted the sociocultural contexts of its endeavors. The work of Kuhn (1962), Harding (1998), Traweek (1993), Bazerman (1988), and others in the areas of philosophy, sociology, anthropology, and rhetoric of science show how knowledge formation in science is shaped by the economic, cultural, and political contexts in which science activity is embedded. Harding applied standpoint theory to the analysis of science knowledge production, holding that excluding social factors from analysis of science epistemology lessens objectivity. She argued that strong objectivity begins with the socially situated contexts in which science operates and yields greater understanding of the ways and directions western science knowledge developed. Ogawa (2004: 2) defined science as a "rational perceiving of reality" where rational is defined by those within the culture. He distinguished between western modern science and indigenous science as follows: "While Western Modern Science is defined as 'a collective rational perceiving of reality which is shared and authorized by the scientific community', indigenous science is defined as '*a culture-dependent collective rational perceiving of reality'*."

2.2 Science as Verb (Sciencing) and Science as Noun (Scientific Knowledge)

The processes of science – *doing science* – and the products of science – *knowledge claims resulting from doing science* – have been central to understanding the nature of any knowledge system about nature and naturally occurring events. Debates that concentrate on either the verb/process or the noun/knowledge do not inform the understanding of how culture, language, and prior knowledge influence science practice – construction of knowledge claims and explanations – or science learning – construction of understanding of these knowledge claims and explanations. Doing science and building knowledge about nature and naturally occurring events are fundamental to knowing how to facilitate learning about these same ideas; the verb and the noun are intimately connected in the informal and formal learning environments.

Brian: I do not believe that science education researchers or scientists view science as being constructed in isolation; that is, it is either constructed by an individual with no input from anyone or nature speaks and we simply relay the information. Scientific knowledge is about social construction – the concept of scientific argumentation requires the need for discourse communities. However, I would suggest that the processes of western science result in particular forms of knowledge that have a different basis than indigenous knowledge. The question is whether we use the word science in multiple ways or use it in a more unitary manner, recognizing that there are multiple forms of knowledge about the same phenomena.

Pauline: I think science educators must recognize that the word science may be used in school science to mean knowledge gained through particular methods, but that it also is used in ways implying expertise and authority, as in Webster's definition of scientist as an expert in one or more sciences. Thus, a theme connecting these papers is that coming to know western modern science in classrooms where the language and ideology of the dominant cultural group prevail often involves issues of power and knowledge. If science education is viewed through a sociocultural lens, as implied by Ogawa's (2004) multiscience perspective and Aikenhead's (2006) analysis of areas of difference for indigenous and western science knowledge systems, it would be seen as a contested terrain wherein teaching and learning of science are affected by the different interests and ontologies of home, school, and science cultures. From a sociocultural perspective, every learner of science crosses cultural borders as she/he learns to understand western modern science as a particular way of constructing knowledge and contrasts this new knowledge with their prior, informal, intuitive understandings in “God is bowling” (Yore, 2008).

If a core goal of science education is science literacy defined broadly as the ability to participate and communicate in science issues at local levels, then the knowledge, beliefs, and views about nature and the world that students bring to the science classroom are relevant to how school science is taught and learned. Text-based curricula that replace local science relevant to students’ lives further disconnect science learning from students’ familiar worlds. Students from subsistence and indigenous cultures may find the transmission of home language and knowledge interrupted or discouraged as old-fashioned and irrelevant. The sharing of knowledge in a respectful environment is especially important for students from indigenous and aboriginal cultures that have developed a body of knowledge about the world based on close observation, record keeping, and communication transmitted and encoded in frameworks (e.g., myth, metaphor, dance, chant, star compass) that differ from the writing and documentation developed as western science. Including indigenous knowledge about nature in the science classroom provides points of entry into western science for students who have historically been underserved and underrepresented.

Non-identical knowledge and ways of understanding the natural world are not surprising, given the variety of cultures with different interests and needs to know. For example, should culturally significant plants developed by indigenous peoples be experimented on and become intellectual property for profit? At my home institution, the University of Hawai‘i at Mānoa, indigenous Hawaiians who had developed several hundred cultivars prior to Western contact protested recent patents on three cultivars of taro, their staple food, obtained through crossbreeding a Hawaiian taro (*kalo*, *Colocasia esculenta*) with one from Palau for disease resistance (Center for Food Safety, 2006). According to spokesman Walter Ritte:

> Hawaiians would never dream of patenting or genetically manipulating *kalo. Kalo* is a gift handed down to us by our ancestors. Hawaiians believe *kalo* is the first born (named *Haloa*), and is our elder brother. We have a *kuleana* or responsibility to honor, respect and protect *Haloa*, so he in turn will sustain us.

Six months later, Vice Chancellor for Research Gary Ostrander responded (“UH agrees,” 2006):

> The University of Hawai‘i has a strong desire to maintain appropriate respect and sensitivity to the indigenous Hawaiian host culture. Taro is unique to the Hawaiian people in that it represents the embodiment of their sacred ancestor. As such, it is appropriate to make an exception to our standard policy of holding all patents.

In summary, in trying to answer the question of what does it mean to come to know in science, we agree to disagree. Consensus was not the central goal of these deliberations; awareness of the critical issues was! There are many similarities in the epistemological beliefs, processes, and practices of western modern science and indigenous science – rational thinking, observations, speculations, etc. – but there are different types of knowledge. We do, however, suggest that these different types of knowledge should be viewed as parallel forms of knowledge. We do agree that the ontological foundations of scientific explanations differ amongst the various knowledge systems about nature and naturally occurring events. We do not believe that we should see one form being superior to the other. Value judgments frequently get in the way of full, rich discussions of culture, language, and knowledge systems related to achieving science literacy for all. The sociopolitical agenda – cultural isolation/ sovereignty, assimilation, two-way border crossing – has issues that are best addressed by the parties involved and not as part of the general debate about knowledge systems dealing with nature and naturally occurring events. However, everyone involved in this special issue of L1 wishes to avoid the disaster where people fall between cultures without the support of any culture and related beliefs and values.

3. HOW DOES THIS CONCEPT OF SCIENCE TRANSLATE INTO PEDAGOGICAL PRACTICES?

In framing this paper, we were interested in having some discussions about the impact of different views of science on what does or should occur in science classrooms. The authors of the articles in this special issue discuss various and particular aspects of their own situations; and as can be seen, there is a diversity of views and orientations toward classroom practices represented. While the discussion below does range over a number of different points, we would remind the reader that these differences are important in moving the debate forward. Both Pauline and Brian agree that while we have differences, the discussions do help us articulate our own understandings better. Importantly, science is practiced across many disciplines and in many different settings; and science is taught in different settings using different methods. We need to begin to strive to align these educational goals and practices.

3.1 Science Literacy for All

Science literacy for all has been identified as a common feature in many international science reforms (Hand, Prain, & Yore, 2001). Most of these educational reform documents contain sociopolitical agendas as well as educational goals, population targets, and pedagogical assumptions. There is not full agreement on what science literacy, as the central educational goal, involves other than it appears to involve an understanding of some big ideas about science and a general, fundamental ability to speak, understand, read, write, represent, and interpret science discourses leading to a full and informed participation in the public debate about science, technology, society, and environment issues (Norris & Phillips, 2003; Yore & Treagust, 2006). Like earlier science education reforms, science literacy for all must be transformed into school science programs composed of curricula, instructional resources, teaching approaches, and assessment techniques. Aikenhead (2006: 1) stated that:

> Educators inevitably rationalize pipeline school science as serving two main purposes for [their] students: their need to understand science well enough to appreciate its national importance, and their need to be literate enough to receive scientific messages expressed by scientific experts.

What is science literacy for all? Is it general literacy for citizens and not elite literacy for the small percentage of students who select and enter science-related careers or take another postsecondary science course?

Brian: We have moved past old visions of science literacy being the ability to read science textbooks and to answer science questions. Importantly, there is a need for students to understand the basic structure of science and how they can engage in the communication of science problems/issues that arise in their lives. We need to provide students with opportunities to talk, read, and write about issues across a broad range of topics and debates. As students have to move between different discourse communities, we need to encourage them to begin to see how knowledge is valued within these different communities. Osborne and Freyberg (1985) introduced the concept of children's science to indicate that children hold multiple forms of knowledge about the same concept. The same concept holds for their movement between different discourse communities – each community may hold different views of the same knowledge. However, students need to understand that when dealing with science there is a need for the argument structure of science to be used to justify and communicate the ideas or phenomena under study.

Pauline: I agree with the broad interpretation of science literacy as the ability to participate in the public debate about and communicate in science issues at local levels. To achieve this goal, you need to transition students from their varied discourse communities into that of western modern science, L-3. A study by Chinn and Hilgers (2000) illuminated this process. Undergraduate evaluations revealed that highly rated, writing-based, science and engineering courses were characterized by frequent opportunities to listen/speak/write/read in collaborative learning communities, discuss writing and assessment guidelines, experience peer and instructor feedback, and write and present to audiences other than the instructor. Instructor interviews showed knowledge of their professional discourse communities framed course design. The most highly rated course included field-based research, writing a scientific report, and presenting it to the relevant agency. These classes exhibited hallmarks described in the National Science Education Standards (NSES) (National Research Council [NRC], 1996) of: (a) inquiry-based science, (b) recognition of diversity and participation of all students, (c) ongoing assessment of teaching and student learning, and (d) communities of science learners applying the skills, attitudes, and values of scientific inquiry.

Given what we know about indigenous science and western science (multi-science), we need to consider multiple literacies that more closely reflect how traditional knowledge systems are developed and communicated (Stephens, 2000). Metaphorical or abductive thinking (a type of reasoning from effect to cause), trust in wisdom and respect of all things, indigenous ecological knowledge and local verification, oral records and traditional story telling, cultural practices, and graphic displays provide entry points to western science and technology especially relevant to place-based applications, sustainability, cycles, and interdependence.

I provide case studies of five Native Hawaiian teachers enrolled in my culture-science curriculum class who ground their community-based environmental science programs in cultural values and practices (Chinn, 2006, April; in press). Though none was a science major, each took on personal responsibility, *kuleana,* to care for the lands and sea that sustain all life, *malama i ka ʻaina*, *malama i ke kai*. In 2003, Michelle, who teaches Polynesian voyaging, chose to honor a recently deceased Native Hawaiian elder. His concern about alien species in his beloved coastal waters motivated her to form a learning community of scientists, canoe club members, and students who remove alien seaweeds, restore native seaweeds, and monitor water quality, fish and invertebrate populations. Michelle's predominantly Native Hawaiian students learn science as practiced in their familiar worlds – not to learn science, as they do not receive science credit, but to address cultural values oriented to sustainability.

I would suggest that science literacy for all must target all people, not just the elite few who may take additional postsecondary science courses and select a science-related career. Aikenhead (2006: 1) stated that school science's purpose is "to develop students' capacities to function as responsible savvy participants in their everyday lives increasingly affected by science and technology." Clearly, this fuller and informed participation is context-driven and involves place-based, science/technology/society/environment issues.

3.2 Pedagogy – Not Philosophy

The publication of recent education reform documents in most countries and content areas has gone beyond the normal prescription of learning outcomes to reaffirm the importance of teachers, teaching, and learning as primary influences on students' thinking, achievement, and science literacy. Collectively, these documents provide strategic visions of what we should teach, how we should teach, and how we should teach teachers to teach. Unfortunately or fortunately, the visions are not in sharp focus or detail; and they tend to stress philosophical statements rather than pedagogical practices. An analysis of the reform documents in the U.S.A. for English language arts, mathematics, science, social studies, and technology revealed several common issues: a focus on *all* students, literacy as a learning outcome, and constructivism and authentic assessment as pedagogical intentions (Ford, Yore, & Anthony, 1997). Little attention has been given to developing a concise, clear image of constructivism and associated pedagogical practices for western science – much less multiscience – that would apply to all students in a multicultural context (NRC, 1996: 52) (See table 1).

When the full spectrum of changing emphases in science teaching is considered in the context of worldviews, definitions of science, ontological and epistemological underpinnings, judgment criteria for what to believe or do, locus of control for the learning agenda, sources of pedagogical structure and classroom management, and roles of language and discourse, it becomes apparent that several versions or faces of constructivism are possible, ranging among information processing, interactive-constructivist, social constructivist, and radical constructivist approaches (Yore, 2001). All of these perspectives embrace the basic constructivist assumptions about the role of prior knowledge, the plausibility of alternative ideas, and the resiliency of these ideas. But each perspective differs on specific epistemological and ontological views of science and other classroom factors. The locus of mental activity and construction of understanding at either or both a private and public level, evidence-driven or consensus-driven knowledge claims, roles of language and classroom discourse to disseminate proven claims or to reveal and debate the variety of alternative interpretations, and pedagogical structure for learning agenda and control may be dictated by the teacher, learners, or shared by the learner and the teacher.

Table 1. Changing emphases in science teaching

Less Emphasis on:	*More Emphasis on:*
Treating all students alike and responding to the group as a whole	Understanding and responding to individual students' interests, strengths, experiences, and needs
Rigidly following curriculum	Selecting and adapting curriculum
Focusing on student acquisition of information	Focusing on student understanding and use of scientific knowledge, ideas, and inquiry processes
Presenting scientific knowledge through lecture, text, and demonstration	Guiding students in active and extended scientific inquiry
Asking for recitation of acquired knowledge	Providing opportunities for scientific discussion and debate among students
Testing students for factual information at the end of the unit or chapter	Continuously assessing student understanding
Maintaining responsibility and authority	Sharing responsibility for learning with students
Supporting competition	Supporting a classroom community with cooperation, shared responsibility, and respect
Working alone	Working with other teachers to enhance the science program

Brian: We have to be a little careful to distinguish the teaching of the science from what needs to be considered as science. The difficulty of presenting a within-culture view only – for example, aboriginal science – is that nearly all students in their daily lives are moving between cultures and their related views. The cases that have been presented in this special issue are about students who are in a dominant culture where the recognized science is western science and they come from a minority, traditional, or indigenous culture. The concept of science as a methodology has been presented countless times but is centred on argument and patterns of claims, evidence, and warrants. I think this is critical for us to understand where the emphasis of the arguments is – is it about what we call science or is it about knowledge the students bring, how they construct knowledge from their prior knowledge and current experiences in a sociocultural context, and the pedagogy we should adopt? Are we rushing to claim different ways of seeing the world as ways of doing science or ways of constructing knowledge within particular cultural groups? It seems to me that we need to adopt a between-cultures view and understand that we can and do have parallel worldviews, that there is traditional knowledge and there is science knowledge. One does not deny the existence of the other, but they are not the same thing. We then need to deal with the question of the appropriate pedagogy to be adopted that is sensitive, respectful, and effective.

Pauline: I may seem repetitive; but we have to recognize that a key issue addressed in many of the papers is that school science contexts involve language, cultural identity, and power. If we as science educators hold the goal of science literacy for all students, we need to be cognizant of these issues. We need to acknowledge different worldviews and epistemologies and prepare our teachers to engage students in culturally and/or locally relevant activities as noted above that support entry into ways of knowing and communicating of science discourse communities. In a review of research on multicultural science teacher education, Arambula-Greenfield (2005) noted resistance among science teachers to incorporating multiculturalism and student diversity into their instruction, given their understanding of science as objective and impersonal. Teachers who view science as an absolute body of knowledge about reality and science teaching as the transmission of knowledge are not likely to consider how meaningful their curriculum and instruction might be from the perspective and experiences of culturally diverse learners. We agree that this traditional view of science and science teaching must be challenged and replaced with a face of constructivism that is sensitive to students' needs and respectful of the culture, language, and prior knowledge and experiences as assets, not deficits.

What is clear from contributors is that home language and knowledge are valued as providing frameworks for knowing and being in the world and providing cultural identity. Rivard and Cormier (2008) consider L-1 (home language), L-2 (mainstream language of schools), and L-3 (academic discourse) analyses inadequate to deal with the ways cultural views, attitudes, and values held by students from non-mainstream cultures and those held by teachers from the dominant culture impact on learning and school success. They address issues connected to power, politics, and social class in mainstream schools that lead to cultural conflict, inferiority, and the loss of cultural identity and home language experienced by marginalized, Francophone students.

The contributors describe patterns of lower success of linguistically and racially marginalized students in mainstream schools, suggesting they find few entry points into school science. Guo (2008) notes that Taiwan's aboriginal students have low success rates and that, despite mainstream Han students doing well in school science, outside of school Chinese cultural values and beliefs hold sway. The way that nature is understood as larger than and not susceptible to human control remains fundamentally Chinese, even 'unscientific' from a western science perspective based on evidence and causality. Home culture and school science culture exist in parallel though intersecting worlds. This suggests the important role that cultural identity plays when L-3 not only differs from L-1 but also is associated with a different worldview. The authors in this special issue indicate that cultural groups have multiple ways of understanding the world with western science methods appropriate in some domains and indigenous cultural perspectives appropriate for others. These cross-cultural studies suggest that, for students whose cultures and languages are most distant from the communication and knowledge structures of western science, success in school science is contingent on providing multiple entry points into science through participation in science activities and sharing of viewpoints in a respectful environment. Snively and Williams (2008) emphasize the importance of recognizing the sociopolitical context of schooling for aboriginal and indigenous peoples who may resist it as leading to loss of cultural identity. This suggests the need to provide teachers with community-based learning experiences (Chinn, 2006) to sensitize them to the role of culture in teaching and learning and to provide authentic learning connected to student and community science interests.

3.3 The General Issues of Relevance and Identity

Some issues and concerns with science, science curricula, and science teaching are cross-cultural and within-culture concerns. Relevance, identity, and motivation are pressing issues within a monoculture as well as across cultures (Brown, 2004; Lee, 2005; Yore et al., 2004). Aikenhead (2006) promoted a humanistic approach to science instruction not just for the cultural minority but for all learners. Other science educators have promoted science-technology-society-environment, applied science and technological design, and high-interest topics for girls or boys approaches as motivational solutions to the low interest in science and engineering (relevance) and to overcome the lack of personal connection to the traditional images of scientists and engineers as old, white, male nerds (identity).

Aikenhead (2006) and Stephens (2000) provided guidelines for developing culturally responsive and respectful science curricula. They identified features that equally apply to many diverse groups of students, such as recognition that individuals are composites of many lived experiences and genetic predispositions, labels encourage unwarranted generalizations, translate between languages with caution since direct translations lose cultural nuances and encourage misinterpretations, avoid tokenism, recognize the value and limitations of place-based knowledge claims and explanations, learning is a journey toward wisdom, some knowledge is holistic and cannot be deconstructed or reduced to a set of binary cause-effect interactions, knowledge is intergenerational, and marginalized groups can be engaged by articulating and acknowledging these people. Stephens (11) identified common ground (intersection) between traditional native knowledge and western science – "Organizing Principles, … Habits of Mind, … Skills and Procedures, … [and] Knowledge." Gadicke (2005) attempted to use these guidelines and the U.S. National Science Teachers Association (2000) position statement on multicultural education – nurturing all children by incorporating content contributions from many cultures and utilizing culturally related ways of knowing and instructional practices – to incorporate Ktunaxa Nation's knowledge and applications about water in the British Columbia K-12 science programs. She found that such curriculum development efforts needed to consider ownership of the knowledge and applications, culturally appropriate ethics and protocols to access these ideas, and the sponsorship of a trusted community member to facilitate these activities.

Brian: My argument would be that all students would connect to this – we have declining enrollments in science at university – not just a disconnect from non-mainstream. I am a little intrigued by who are classified as mainstream. Arguments can be made for low socioeconomic status children, females not connected to science, and low-achieving males – all these groups would see the same connectedness if the same strategies were adopted. This special issue is about L1 learners so the argument is framed along those lines, but I would argue that the ideas should not be seen as solely applying to one group. I think they have application across a broader spectrum of students who learn science in the company of scientists and see how science knowledge and discourse can lead to future careers and endeavors. Bryan & Allexsaht-Snider (2008) illustrate how two teachers in rural Mexico prepared their students to identify with science and to move back and forth across the science of their small villages and the science they might encounter in advanced study in high school or university. The issues of relevance, identity, motivation/interest, and instructional resources are demonstrated as within-culture variables; but Fakudze and Rollnick (2008) illustrate the same factors as cross-cultural variables.

Pauline: I agree that all students would benefit from learning science in ways that connect to their lives and that this should be a focus of science teacher education. Gross (2006) reported that adult science literacy in the U.S.A. stands at 17%, doubling over the last 20 years. Access to science has cross-cultural aspects. Mainstream students from groups that shape the prevalent attitudes, values, and practices of dominant society are more likely to have family and friends in science and related fields and less likely to experience the same sociocultural barriers as students from non-mainstream, underrepresented groups. Two Native Hawaiian female engineers said their interest in science developed through seeing male relatives at drafting tables, visiting work sites, hearing work-related stories, and playing number games (Chinn, 1999). They also spoke of negative school science experiences due to some teachers' and peers' disparaging comments relating ethnicity to science ability. Their reports suggest how identity and culture affect learning and interest of learners on the periphery of science and the importance of providing all students with positive science experiences long before their engagement in the formal communication structures of western modern science. At the University of Hawai'i at Mānoa, the cross-cultural, undergraduate Konohiki Program explicitly connects Hawaiian Studies and Botany from conceptual framework through implementation (http://www.hawaii.edu/huikonohiki/index.html), as does my program for culture-science curriculum and professional development (http://malama.hawaii.edu). The culture-science elements of these programs could provide ideas for those interested in place-based and culture-based science education.

3.4 Instructional Principles for Border-Crossing or Cultural Isolation

Many of the concerns in the six case studies deal with the effects of colonization, assimilation, cultural restoration and language conservation, and other sociopolitical issues dealing with sovereignty, land claims, and addressing past injustices. Awareness of these factors is needed to ensure that history does not repeat itself and that informed decisions about science education, curriculum, and instruction are made today and in the future.

Brian: Within-culture views of science can be what that culture frames science as being (McKinley & Keegan, 2008). These within-culture decisions are rightfully the realm of the peoples involved or empowered with such societal/cultural decisions: elders, elected officials, monads, hereditary rulers, etc. These decisions may differ from competing views of other cultures and nations, such as North America's decision to drive on the right hand side of the road as compared to England's decision to drive on the left hand side of the road. There is no problem as long as North American drivers develop parallel understanding and skills for crossing into a different world. Some North American drivers learn other coping strategies like not driving in England and walking or taking the bus, underground, or taxi. That is, the within-culture view means that a person must stay in that culture or take on multiple understandings of phenomena when moving away from the culture or communicating with others who have different understandings of nature and natural systems. Examples may be found within western societies as well, where belief systems lead to theories about the world that conflict with science processes of applying evidence and negotiation to construct knowledge and theories about the natural world. This is critical in the conversation about what is science. Between-culture views become much more difficult because different groups want to position themselves as suggesting that there are multiple views about what is science; however, there is a dominant perspective that has guided the frame of science for the last 400 years. The concept here is that western science – the predominant view used across the globe – requires particular sets of discourse patterns and argument structures.

Pauline: I agree that to enter the world of western science one learns to use particular ways of communicating. Bazerman (1988) described the construction of the experimental report as developed by Newton and the European contexts in which it developed. However, as noted by Rivard and Cormier, Fakudze and Rollnick, McKinley and Keegan, and Snively and Williams (2008), the obligation to do this in school science may resonate with control and colonialism. Those who wish to enter a discourse community accept the linguistic and cultural identity of that community (Gee, 2001) but retain other identities in other communities (Chinn, 1998, 2002). This two-way border-crossing model needs specific consideration of the match amongst culture, language, and prior knowledge/experiences and the target learning outcomes and instructional activities. Some case studies are more concerned with this approach of acculturation-not-assimilation than others.

3.5 Linguistic Devices and Patterns

Western science assumes a worldview that promotes inquiry, descriptions, and explanations that can be generally applied across numerous places and that involve physical causality relating sets of variables in a cause-effect mechanism. This process has been significantly influenced by print-based symbol systems composed of words, signs, numerical formulas, and visual adjuncts. Indigenous science assumes a worldview that promotes place-based explorations, descriptions and explanations rich in metaphors, and causes based in magic, mystery, and spiritualism. These claims about nature and naturally occurring events have been retained and stored within well-established oral traditions.

Brian: We are concerned with increasing access to science discourse of those who have been less successful; thus, we must listen to the learner. The NSES (NRC, 1996) pointed out that multiple views based on beliefs, myths, etc., are valid for people but they are not western science. In terms of broader participation in science by different groups, I would agree that this can or does change how discourses may be conducted. However, it does not change what is the fundamental epistemology of science, that is, the processes of scientific inquiry and argumentation. Importantly, we need to understand that there are particular language characteristics that exist in within-culture views, where science is viewed from an aboriginal perspective. Most of these cultures have an oral tradition or have not developed written language practices that are symbolic of other cultures. This can be seen as critical in how science is developed as a building of the written record, leading to much contested knowledge, as opposed to oral language where knowledge is passed down in a less contested manner.

Pauline: Myths may be a different way to pack knowledge about nature in metaphor, such as that of the volcano goddess Pele whose travels through the Hawaiian Islands in search of a home reflect the age sequence of the volcanic chain. This is not western science but may be connected to western science knowledge of volcanoes. Including non-mainstream, cultural ways of knowing and describing the world and bridging it to western science knowledge respects a student's culturally rooted discursive identity. More cultural diversity among scientists can enrich conceptualization, discourse, and questions to explore. Increasing community awareness of issues, such as invasive species and emerging infectious diseases, has increased the need for involvement of all citizens, including indigenous peoples, with long-term ecological knowledge about specific places (Kaneshiro et al., 2005).

Much knowledge is passed down without change in oral cultures; but knowledge about the environment is being constantly updated, discussed, and acted upon based on an observable and physical world (Snively & Williams, 2008). Cultures have different knowledge domains. Teachers who ask students to engage in written and oral science discourse seldom recognize this includes the identity of the dominant group. Brown (2004) used the notion of discursive identity in his analysis of marginalized students who resist taking on these markers. He recommended that more inclusive forms of discourse be part of instruction, including inviting students to bring their experiences and knowledge of the topic into the learning community. He suggested that science discourse be explicitly taught at a later stage of instruction. This pedagogical approach values the experiences of students and their entry into a particular discourse community that would apply multiple representations involving many modalities and embrace multiple literacies. Michelle's student-made video of their Maunalua Bay project matches images to excerpts of journals written during three 24-hour immersions that included navigation training and an overnighter on Hokulea, the double-hulled canoe that reconnected Polynesians to their open ocean voyaging traditions. Their images and discourse so clearly reveal their multiple positions within school, scientific, and Native Hawaiian communities that evaluators of

Asian and Pacific Island programs at the National Science Foundation requested a copy and I use it in my teacher education classes.

3.6 Insights into Developing Culturally Sensitive and Respectful Science Literacy Curriculum

Science curricula and instruction programs developed over the last 45 years claim to move science instruction toward more authentic and relevance experiences in science that are within the cognitive levels and interest of the target populations. Many of these programs involve science inquiry, technology design, and contemporary and popular topics amongst the target audiences' interests. Few of these curricula have addressed cultural differences, sensitivity, respect of divergent views, and the literacy or discourse component of science literacy.

Brian: I agree that not much attention has been paid to the cultural issues related to science. While the emphasis has been on inquiry-based strategies and exploring what children know prior to instruction, there has been little attention given to how students' cultural knowledge about nature impacts classroom science teaching and learning. Here I am suggesting that, if prior knowledge is important to constructivist science teaching, then planning of curricula needs to explore and use the link between the cultural knowledge students have and how this will help or hinder the understanding of the science ideas being addressed in the classroom. Recognition needs to be given to cultural knowledge not being simply those cultures that are easily recognized; for example, in northwestern Iowa, there is a strong Scandinavian history of farming with descendents coming to schools with strong values that are shaped by their culture and are not necessarily aligned with the mainstream, even though we would classify them as being part of that group. I believe we need to plan and base instruction on what students bring; otherwise, there is great difficulty for many students in making connections to the knowledge being dealt with in the science classroom.

Pauline: I agree. Ethnographic studies in communities of practice in Hawai‘i (Chinn, in press) reveal authentic science is in reality transdisciplinary and negotiated, producing multiple literacies. This suggests that school science, as the cultural arena in which learners negotiate new discursive identities, needs to allow these spaces. This clearly goes beyond science education as transmission of information and recognizes learners' multiple perspectives. Bryan and Allexsaht-Snider (2008) suggest science educators follow the NSES (NRC, 1996) to bridge students' familiar worlds with school science. Rivard and Cormier (2008) suggest strategies to engage students in science in ways that do not disconnect them from their culture and language. McKinley and Keegan (2008) delineate the struggle to develop a Maori science curriculum in the context of western models of science. This suggests science teachers must learn to be curriculum developers able to contextualize science instruction to engage all learners, especially those whose worldviews differ from those of western science. For example, replacing phenolphthalein as an indicator in acid-base reactions with red cabbage extract connects the topic of pH to familiar realms. In Hawai‘i, extracts of red hibiscus and native berries are local indicators, shells and coralline sand serve as bases; and kukui nuts, called candle nuts in English after their use as a traditional source of light, are used in calorimetry.

Where teachers' cultures and students' home cultures are very different, teachers benefit from experiences directly connecting culture and science (Chinn, 2006). Lee's (2005: 501) review of research with English language learners noted, "Effective science instruction must consider students' language and culture in relation to pedagogical aims." One way to prepare teachers who are not familiar with their students' culture is through culture-science immersion in which teachers participate in communities of practice that address science issues of common interest. In my current project (Chinn, 2006; in press), five Native Hawaiian teachers (none of whom are science majors) recognize that western science is valuable for understanding and caring for the lands that sustain – *malama 'aina*, a core cultural value. As teachers connect school science to the unrecorded ecological knowledge of Hawaiian communities, they are in a unique position to lead communities of practice in which scientists, students, and Native Hawaiians employ western science tools to monitor and restore local ecosystems. Their culture-science curricula map onto a cultural framework – precontact Hawaiians systematically assessed their environments and made decisions on resource use to ensure sustainability.

3.7 Moving Classroom Practices toward Science Literacy for All Cultures and All Students

What the authors have been promoting in this special issue is NOT something that literacy, multicultural, indigenous, and science education communities are going to do overnight. But the first step for you, as readers of this issue of L1, has already started the needed movement – communication among these communities and awareness of the basic underlying issues as recommended at the 'First Island Conference' (Hand et al., 2003; Yore et al., 2004). Does a constructivist framework provide foundation for and insights into designing and evaluating teacher education and professional development programs and classroom practices that attempt to engage and promote science literacy for all? The operant issue is teacher education – not teacher training (Yore, 2001). Clearly, we need to produce beginning and practicing teachers who are critical thinkers and reflective practitioners and to catalogue effective instructional programs and conduct cross-case analyses to identify critical design principles and classroom practices in these exemplary programs. This education and development process will involve more than just mimicry, mechanical use, and classroom management; it will need to involve an integrated and coordinated effort of the communities involved – scientists, indigenous groups, educators, administrators, and policy makers.

The development of critical thinking – in which teachers are challenged by pedagogical issues and required to deliberate about alternative solutions, to reflect and to justify their instructional decisions – should be a fundamental part of professional education. It is essential that the on-campus components of a teacher education program and professional development activities present an internally consistent rationale for and expectations of teaching to achieve science literacy for all. Lecturing about the nature of science and constructivist teaching in education and professional development courses and traditional chalk-and-talk academic science courses with verification laboratories have little impact on teachers' views of science as a tentative, speculative process of knowledge claims augmented with evidence and canonical science ideas. Furthermore, there needs to be a shared repository of effective public policies (McKinley & Keegan, 2008; Snively & Williams, 2008), curriculum guidelines (Aikenhead, 2006; Stephens, 2000), and instructional programs (Bryan & Allexsaht-Snider, 2008; Gadicke, 2005; Klentschy & Molina-De La Torre, 2004) that might serve as models for embryonic efforts, even if they will have limitations because of the culture, language, place, and context-specific nature of most of these resources.

Brian: Learning science involves the need for students to talk, read, and write about science in ways that promote scientific argument as a means to building understanding of the topics. Teachers need to use a broad range of possible literacy practices to help engage students in science and to build understanding. The work that my colleagues and I have been engaged with over the last ten years has emphasized the need to embed language practices within the context of the science teaching and learning context. We do not believe that we should teach students the language practices of science separate from science. Thus, we would argue that teachers should explore all the possible language practices of talking, reading, and writing about science, as well as incorporating multimodal representation and technology as a tool for representation, wherever possible. Such practices may include oral history, writing to different audiences, or engaging in debate, to name but a few. As a community, we need to continue to explore what are the best language practices that enable all students to better engage with and understand the science being explored. There is a need to explore these strategies and approaches across all the cultures within our classrooms – not isolate any one culture or pay attention to only one culture. We have found that when students use writing-to-learn strategies within science classrooms we have been able to close achievement and gender gaps. This research and its potential needs to be continued.

Pauline: Research conducted by Kline (2006) in five general chemistry classes in a school in which Hawaiian students were overrepresented among failures (44% of failures, 38% of population) suggests that connecting students' lives to science learning leads to higher academic performance. For a unit on water spanning more than an academic quarter, in two experimental classes ($N = 57$) where interpersonal and place-based pedagogies (e.g., cooperative learning, stream visit), lectures, and two home/community-based homework assignments connected to students' lives, Native Hawaiian students ($n = 23$) had significantly ($p < 0.05$) higher grades (83.0 vs. 74.7%) than their Native Hawaiian peers ($n = 40$) in three control classes ($N = 83$). Tests and other assignments were identical. Students in the experimental class had two extra homework assignments (Chemistry in My House and Story of a Water Droplet) that received the highest scores of all homework assignments (83 vs. 51.4% for regular homework). These results suggest that science teaching that connects to students' lives supports the entry of all students, especially those who are persistently underrepresented into western science ways of knowing about the natural world.

4. CLOSING REMARKS ABOUT FUTURE CURRICULUM DEVELOPMENT AND RESEARCH

In conclusion, we agree there are different views and definitions of science indicating different ways of understanding the world. This is captured in Ogawa's (2004: 2) broad definition of science as "a rational perceiving of reality" with western modern science defined as "a collective rational perceiving of reality which is shared and authorized by the scientific community" and indigenous science defined as a "a culture-dependent collective rational perceiving of reality." A 17% scientific literacy rate among adults in the United States and even lower rates in Canada, Europe, and Japan (Gross, 2006) suggests that there is much work to do in the area of L-3, enabling students to use the language, practices, and discourse of western modern science.

The papers in this special issue present an international perspective on the cultural contexts of moving between L-1, the language and worldview of home and community, into L-2, the language of school, and into L-3, the language of science where language is not simply a neutral, transportable media for conveying western science ideas and concepts. Problems and issues have been presented, and some promising curricular and pedagogical strategies described. Directions for further research include a call for researchers especially of indigenous and underrepresented groups to contribute to a deep and nuanced understanding of the role of culture in science and science education. Some questions to be considered include:

- What characterizes effective science programs for indigenous or underrepresented students?
- What, from the host community perspective, characterizes a successful science student?
- What are the science concerns of these groups, and how may these concerns find a place in school science teaching and pedagogy?
- What are the implications for teacher education, curriculum development, and instructional innovations?
- What implications do science literacy for all, as described and promoted in this special issue, have for assessment and large-scale evaluation programs?
- What changes will be needed in postsecondary programs in engineering, mathematics, and physical sciences to facilitate the two-way border crossing promoted by several authors?

Lower science literacy than college graduation rates in the U.S.A., and perhaps elsewhere as well, suggests researchers in a broad range of settings might address these questions.

REFERENCES

Aikenhead, G.S. (2006). *Science education for everyday life: Evidence-based practice*. New York: Teachers College Press.

Arambula-Greenfield, T. (2005, April). *The research lens on multicultural science teacher education: What are the research findings, if any, on major components needed in a model program for multicultural science teacher education*. Paper presented at annual international conference of the National Association for Research in Science Teaching, Dallas, TX, USA.

Bazerman, C. (1988). *Shaping written knowledge: The genre and activity of the experimental article in science*. Madison, WI: University of Wisconsin Press.

Brown, B. (2004). Discursive identity: Assimilation into the culture of science and its implication for minority students. *Journal of Research in Science Teaching, 4*(8), 810-834.

Bryan, L.A., & Allexsaht-Snider, M. (2008). Community and classroom contexts for understanding nature and naturally occurring events in rural schools in Mexico. *L1 – Educational Studies in Language & Literature, 8*(1), 43-68.

Center for Food Safety. (2006, January 12). *University of Hawai'i told to give up taro patents*. Washington, DC: Author. Retrieved May 15, 2007, from http://www.centerforfoodsafety.org/press_release1_12_20062.cfm.

Chinn, P. (1998). A scientific success: Isabella Aiona Abbott and the education of minorities and females. *Teaching Education, 10*(2), 155-167.

Chinn, P. (1999). Multiple worlds/mismatched meaning: Barriers to minority women engineers. *Journal of Research in Science Teaching, 36*(6), 621-636.

Chinn, P. (2002). Asian and Pacific Islander women scientists and engineers: A narrative exploration of model minority, gender and racial stereotypes. *Journal of Research in Science Teaching, 39*(4), 302-323.

Chinn, P. (2006). Preparing science teachers for culturally diverse students: Developing cultural literacy through cultural immersion, cultural translators and communities of practice. *Cultural Studies of Science Education, 1*(2), 367-402.

Chinn, P. (2006, April). *Native Hawaiian teachers' community-based programs: Grounding environmental literacy in indigenous knowledge and values*. Paper presented at annual international conference of the National Association for Research in Science Teaching, San Francisco, CA, USA.

Chinn, P. (in press). Connecting traditional ecological knowledge and western science: The role of Native Hawaiian teachers in sustainability science. In A. Rodriguez (Ed.), *The multiple faces of agency: Innovative strategies for effecting change in urban school contexts*. Rotterdam, The Netherlands: Sense.

Chinn, P., & Hilgers, T. (2000). From corrector to collaborator: The range of instructor roles in writing-based natural and applied science classes. *Journal of Research in Science Teaching, 37*(1), 3-25.

Fakudze, C., & Rollnick, M. (2008). Language, culture, ontological assumptions, epistemological beliefs, and knowledge about nature and naturally occurring events: Southern African perspective. *L1 – Educational Studies in Language & Literature, 8*(1),.69-94

Ford, C., Yore, L.D., & Anthony, R.J. (1997). *Reforms, visions and standards: A cross-curricular view from an elementary school perspective*. (ERIC Document Reproduction Service No. ED406168)

Gadicke, J. (2005). *Integrating aboriginal knowledge into the elementary science curriculum*. Unpublished master's project, University of Victoria, Victoria, British Columbia, Canada.

Gee, J. (2001). Identity as an analytic lens for research in education. In W.G. Secada (Ed.), *Review of research in education*, 25 (pp. 99-125). Washington, DC: American Educational Research Association.

Gross, L. (2006). Scientific illiteracy and the partisan takeover of biology. *PLoS Biol 4*(5): e167. DOI: 10.1371/journal.pbio.0040167. Retrieved June 11, 2006, from http://biology.plosjournals.org/perlserv/?request=get-document&doi=10.1371/journal.pbio.0040167.

Guo, C.J. (2008). Science learning in the contexts of culture and language practices: Taiwanese perspective. *L1 – Educational Studies in Language & Literature, 8*(1), 95-107.

Hand, B.M., Alvermann, D.E., Gee, J., Guzzetti, B.J., Norris, S.P., Phillips, L.M., Prain, V. & Yore, L.D. (2003). Message from the "Island Group": What is literacy in science literacy? *Journal of Research in Science Teaching, 40*(7), 607-615.

Hand, B.M., Prain, V., & Yore, L.D. (2001). Sequential writing tasks' influence on science learning. In P. Tynjälä, L. Mason, & K. Lonka (Eds.), *Writing as a learning tool: Integrating theory and practice* (pp. 105-129). Dordrecht, The Netherlands: Kluwer.

Harding, S. (1998). Women, science, and society. *Science, 281*, 1599-1600.

Kaneshiro, K., Chinn, P., Duin, K., Hood, A., Maly, K., & Wilcox, B. (2005). Hawai'i's mountain to sea ecosystems: Social-ecological microcosms for sustainability science and practice. *EcoHealth, 2*(4), 349-360.

Klentschy, M.P., & Molina-De La Torre, E. (2004). Students' science notebooks and the inquiry process. In E.W. Saul (Ed.), *Crossing borders in literacy and science instruction: Perspectives on theory and practice* (pp. 340-354). Newark, DE: International Reading Association.

Kline, J. (2006). *Culturally relevant science curriculum: Practical applications*. Unpublished master's thesis, University of Hawai‘i-Mānoa, Honolulu, Hawai‘i, USA.

Kuhn, T. (1962). *The structure of scientific revolutions*. Chicago: University of Chicago Press.

Lee, O. (2005). Science education with second language learners: Synthesis and research agenda. *Review of Educational Research, 75*(4), 491-530.

McKinley, E., & Keegan, P.J. (2008). Curriculum and language in Aotearoa New Zealand: From science to putaiao. *L1 – Educational Studies in Language & Literature, 8*(1), 135-147.

National Research Council. (1996). *National science education standards*. Washington, DC: National Academies Press.

National Science Teachers Association. (2000). Position statement on multicultural science education. Retrieved June 6, 2006, from http://www.nsta.org/159&psid=21.

Norris, S.P., & Phillips, L.M. (2003). How literacy in its fundamental sense is central to scientific literacy. *Science Education, 87*(2), 224-240.

Ogawa, M. (2004, October). *Indigenous science and education of indigenous science: Japan's experiences and implications*. Paper presented at The Role of Indigenous Knowledge in Schools: Science and Mathematics in Pacific Island and Pacific Rim Nations conference, Honolulu, Hawai‘i, USA.

Osborne, R., & Freyberg, P. (1985). *Learning in science: The implications of children's science*. Sydney, Australia: Heinemann.

Rivard, L.P., & Cormier, M. (2008). Teaching science to French-speaking students in English Canada using an instructional congruence model involving discourse-enabling strategies. *L1 – Educational Studies in Language & Literature, 8*(1), 23-41

Snively, G.J., & Williams, L.B. (2008). "Coming to know": Weaving Aboriginal and western science knowledge, language, and literacy into the science classroom. *L1 –Educational Studies in Language & Literature, 8*(1), 109-133.

Stephens, S. (2000). *Handbook for culturally responsive science curriculum*. Fairbanks, AK: Alaska Native Knowledge Network.

Traweek, S. (1993). Cultural differences in high-energy physics: Contrasts between Japan and the United States. In S. Harding (Ed.), *The racial economy of science: Toward a democratic future* (pp. 398-407). Bloomington, IN: Indiana University Press.

UH agrees to give up 3 patents on taro: Native Hawaiians are determining which entity will receive the patents. (2006, June 3). *Honolulu Star Bulletin*, *11*(154). Retrieved May 16, 2007, from http://starbulletin.com/2006/06/03/news/story13.html.

Yore, L.D. (2001). What is meant by constructivist science teaching and will the science education community stay the course for meaningful reform? *Electronic Journal of Science Education, 5*(4). Online journal: http://unr.edu/homepage/crowther/ejse/yore.html.

Yore, L.D. (2008). Science literacy for all students: Language, culture, and knowledge about nature and naturally occurring events. *L1 – Educational Studies in Language & Literature, 8*(1), 5-12.

Yore, L.D., Hand, B.M., Goldman, S.R., Hildebrand, G.M., Osborne, J.F., Treagust, D.F., & Wallace, C.S. (2004). New directions in language and science education research. *Reading Research Quarterly, 39*(3), 347-352.

Yore, L.D., & Treagust, D. (2006). Current realities and future possibilities: Language and science literacy–empowering research and informing instruction. *International Journal of Science Education, 28*(2-3), 291-314.

Ziman, J. (2000). *Real science: What it is, and what it means*. New York: Cambridge University Press.