ELEANOR ABRAMS, PETER CHARLES TAYLOR and CHORNG-JEE GUO

EDITORIAL

CONTEXTUALIZING CULTURALLY RELEVANT SCIENCE AND MATHEMATICS TEACHING FOR INDIGENOUS LEARNING

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Introduction

For over 20 years, mathematical and scientific literacy for *all* students has been the goal for many of the national and international reforms in mathematics and science. However, indigenous students are still underachieving in mathematics and science when compared to majority students (Battiste, 2002; Chien, 1998; Fu, 1999, 2003; Lin, 1999). Indigenous Australian students scored significantly lower in mathematics and science than nonindigenous Australian students in 2009 on the Program for International Student Assessment, reaffirming the trend from previous years (National Center for Education Statistics, 2010a, b, c). In the USA, the National Assessment of Educational Progress testing in mathematics in 2007 found 4th grade scores of American Indian/Alaska Natives at 225 and their White counterparts scoring 248 out of 500, with comparable discrepancies exhibited in both 8th and 12th grades (National Center for Education Statistics, 2010a, b, c). Science testing shows the same trends with fourth grade White students scoring 163 and American Indians/Alaskan Natives scoring 135 out of a possible 300 points. This gap in mathematics and science achievement continues through public schooling. US indigenous high school students participate in advanced mathematics and science courses at a much lower rate than do nonindigenous students, are less likely to pursue Science, Technology, Engineering, and Mathematics (STEM) majors in college, and are underrepresented in STEM careers (US Department of Education, 2010).

Strong contributions have been made in recent years to our understanding of indigenous science (IS), mathematics and science

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education, and the aspirations of indigenous students (McKinley, 2007; Barnhardt, 2005; Aikenhead, 2001; Cajete, 2000; McKinley, 1996). Research has shown that mathematics and mathematics learning is not context-free and value-free in its nature, content, and practice (Barton, 1992; Bishop, 1994) and acknowledges that the learning of mathematics takes place in socially and culturally laden contexts (Zevenbergen, 2003). However, studies show that teachers do not consider the nature of mathematical knowledge construction or the students' culture or context when they teach mathematics in K-12 settings (Matthews, Howard & Perry, 2003). Within mathematics education, there is a call to create culturally relevant pedagogy as one way to support learning among indigenous students.

Similarly, much of the research that explores the reasons why indigenous students do not perform well in science classrooms or perform well on assessments focuses on the epistemological basis of knowledge construction of science and indigenous science (IS). Indigenous science (IS) is described as a holistic, contextualized process that has a high regard for nature in relation to humanity and is the result of observations, thinking, and descriptions over an extended time period (Cajete, 1988). Alternatively, Western modern science (WMS) is described as based on logical empiricism (positivism) and universal principles and has an emphasis on control and manipulation of nature and reliance on observation and experimentation over a limited period of time (Snively & Corsiglia, 2001). The conclusion is that westernized nature of the scientific knowledge is "at odds" with IK construction. In addition, research has found that science teachers do not consider how indigenous students' views about the world might be in conflict with WMS (Aikenhead, Calabrese & Chinn, 2006). As in mathematics education, many science education researchers have called for culturally responsive curricula to be taught in science classrooms with significant populations of indigenous learners.

Clearly, one solution to the achievement gap between majority and indigenous students is that teachers with indigenous students should become familiar with the indigenous peoples' lifestyles, find suitable teaching methods for indigenous students, and integrate IS into the curriculum (Ogawa, 1995; Russell & Russell, 1999; Gibson & Puniwai, 2006; Van Eijck & Roth, 2007; Ogunniyi, 2007).

However, McKinley (2001) calls for reconceptualizing the solution of closing the achievement gap by understanding that designing culturally relevant pedagogy is only one way to engage indigenous students in mathematics and science. She makes clear that researchers and educators

cannot ignore the power relationships in the classrooms or the "relations between dominant and subordinate groups marked by histories of oppression" (p. 75). From this perspective, the curricula, teaching methodologies, and assessment strategies associated with mainstream schooling are based on a worldview that does not adequately recognize or appreciate IS or its associated worldviews (Kawagley & Barnhardt, 1998; McKinley & Stewart, 2009).

Students in indigenous societies around the world have, for the most part, demonstrated a distinct lack of enthusiasm for the experience of schooling in its conventional form (Battiste, 2002). McCarty (2002), in her 20 years of ethnographic work in one Navajo school, found that students were forced to learn in a school system that fails to educate. In other communities, indigenous students leaving small rural village schools to enter a majority school experience obvious differences in living conditions. "Rigid schedules, impersonal relationships, inaccessible faculty, expectation of aggressive verbal participation and spotlighting in class, incomprehensible homework assignments, produce serious conflicts and pressures that require considerable adjustments for many Indigenous children" (Barnhardt, 2004). But even these adjustments are not as difficult to manage as the differences in the ways of thinking that permeate majority schools. Indigenous students trying to survive in the majority school environment must acquire and accept a new form of consciousness (Jane, 2003), an orientation that not only displaces but also often devalues the worldviews they bring with them. For many, this is a greater sacrifice than they are willing to make. Those who do survive in the academic environment often find themselves caught between different worlds, neither of which can fully satisfy their acquired tastes and aspirations, and thus they enter into a struggle to reconcile their conflicting forms of consciousness (Kawagley, 1995; Meyer, 2001). More research needs to be conducted on the role of school science as a colonizing influence that may be causing indigenous learners to "opt out" of the learning of science and mathematics (Abrams, Yen, Blatt & Ho, 2009).

This special issue takes a contextualized and international view of the teaching of indigenous students in mathematics and science classrooms. The focus of the papers within this issue makes explicit the knowledge and resources of indigenous students and examines the classroom structures that can enhance or diminish learning. Too often, indigenous students internalize negative images of their culture created and propagated by the institution of schooling as unable, historically and currently, to be producers of mathematical and scientific knowledge and indigenous students as low-achieving mathematics and science learners

(Kidman, Abrams & McRae, 2010). The papers in this issue were selected because the contributing scholars value the diversity that exists within communities and seek to capture perspectives that might support the excellence of indigenous students in science and mathematics and create science and mathematics classrooms that consciously build inclusive learning communities.

The Definitions of Indigeneity

We realize that the categories of race and racialized identities are not static, inert classifications. Rather, race, like many of the other identities held by a person, is fluid and can become more or less dominant depending upon the surrounding context and culture (Buxton, 2006; Brayboy, 2005). Therefore, most fixed definitions of what is indigenous are problematic and create confusion because of the variety of groups that are trying to be included in the one definition. It is clear from the papers in this special issue that the indigenous cultural experience is not the same for everybody, therefore, nor everyone who identifies with a particular indigenous culture produce knowledge the same way, nor do different indigenous cultures produce the same knowledge (Kincheloe & Steinberg, 2008).

The United Nations (UN), which does much to support the self-determination of indigenous peoples, has resisted adopting a definition to determine who is indigenous and has actively supported the right of peoples to determine if they are indigenous. However, there are some broad-based criteria cited in numerous UN reports based on the concept of indigenous by Jose R. Martinez Cobo, the Special Rapporteur of the Sub-Commission on Prevention of Discrimination and Protection of Minorities, in his Study on the Problem of Discrimination against Indigenous Populations (United Nations' Department of Economic and Social Affairs, 2004).

Indigenous communities, peoples, and nations are those which, having a historical continuity with preinvasion and precolonial societies that developed on their territories, consider themselves distinct from other sectors of the societies now prevailing on those territories or parts of them. They form, at present, nondominant sectors of society and are determined to preserve, develop, and transmit to future generations their ancestral territories and their ethnic identity, as the basis of their continued existence as peoples, in accordance with their own cultural patterns, social institutions, and legal system. This historical continuity may consist of the continuation for an extended period reaching into the present of one or more of the following factors:

(a) Occupation of ancestral lands or at least of part of them;
(b) Common ancestry with the original occupants of these lands;
(c) Culture in general or in specific manifestations (such as religion, living under a tribal system, membership of an indigenous community, dress, means of livelihood, lifestyle, etc.);
(d) Language (whether used as the only language, as mother tongue, as the habitual means of communication at home or in the family, or as the main, preferred, habitual, general, or normal language);
(e) Residence on certain parts of the country or in certain regions of the world;
(f) Other relevant factors.

Many governments define indigenous peoples as those that reside on the land prior to occupation by colonizers. In fact, several of the authors in this special issue use the government-recognized designations of indigenous people residing within their countries, such as the Aborigines in Australia, the American Indians in North America, and the Maori of New Zealand as cited by Grootenboer & Sullivan, Nam et al, Webb and Kidman et al in this special issue. Other scholars in this issue use the colonizing event to determine indigenous and colonizer. Afonso evokes the occupation of Mozambique by the Portuguese as the defining event in her discussion of the evolution of culturally relevant pedagogy over time. Similarly, Handa and Tippins used the European colonization of the Philippines as the pivotal event to define IS even though many Filipinos do not consider themselves indigenous. Luitel, in his paper, explores how the static representation of mathematics in Nepali schools contradicts the indigenous peoples' beliefs in the Vedic philosophy of Neti-Neti in Nepal. He defines indigenous peoples as a mix of over 93 distinct language groups with a long history of subsistence living and varied Hindu–Buddhist–animist worldviews; a country that has never been colonized directly by an outside political power but whose mathematics education has been indirectly colonized by British curricula conveyed by Indian textbooks and teachers. Kuwahara's research encouraged the students to self-identify their own racial identity and found that students' identity could be overlapping into one or more ethnic groups including Native Hawaiian. In South Africa, Webb selected the isiXhosa mother tongue-speaking science teachers to determine the isiXhosa students and elders to include in his survey. Those self-designations become an important component in the final results and subsequent suggestions about how to support the learning of indigenous students.

As the scholars describe their research in this special issue, the concept of indigeneity plays an important role in many of the theoretical constructs examined in their papers. Some of the key questions arising from these

papers are: What is the nature of IS? How does culturally relevant pedagogy support indigenous learners to learn science? How can we insure ethical research with indigenous schools, teachers, and learners? We consider the UN's premise that it is indigenous peoples themselves who should decide who are and who are not indigenous people and that this standpoint is paramount to the future of supporting the excellence of indigenous learners in schools, colleges, and universities worldwide.

Defining Indigenous Science

Many articles in this special issue examine topics on IS, IK, indigenous knowledge system (IKS), TEK, and funds of knowledge (FoK). For instance, in Webb's study, a sample of isiXhosa mother tongue-speaking science teachers', their pupils', and adult local community members' awareness of Xhosa IK was investigated. It also examined what aspects of this knowledge they value and think should and could be integrated into the school science curriculum and their reasons for suggesting that it should (or should not) be incorporated. Findings from Kidman, Yen, and Abrams' study suggest that the peripheral positioning of indigenous culture and knowledge within the science curriculum in developed nations underpins a series of tacit pedagogical codes that contribute to indigenous student disengagement with the subject. Maintaining that IKS is not only about "knowledge" but also sociocultural values, ontologies, and epistemologies, and to ignore them is a forged victory for IKS, Afonso argues that we need to find legitimated theories to integrate IKS in order to counteract the practice of teaching IKS in science classrooms detached from their own sociocultural contexts.

Within the research community of science and mathematics education, the term "indigenous science" is defined and interpreted quite differently by different researchers. In addition to terms such as IK, IKS, TEK, and FoK that various authors use in this special issue, a number of terms such as native science, aboriginal science, local knowledge, traditional knowledge, and traditional wisdom are also used in the literature to describe closely related concepts. However, authors holding different values and theoretical perspectives of science, mathematics, and indigenous ways of knowing may prefer to use a particular term rather than others. Wanting for a commonly agreed definition of IS and/or IK, it is perhaps pertinent to quote from Tippeconnic & Faircloth (2010), as they summarized a number of definitions originally quoted in the *Best Practice on Indigenous Knowledge* website (http://www.unesco.org/most/bpindi.htm#definition):

According to the United Nations Educational, Scientific and Cultural Organization (UNESCO), Indigenous knowledge is "culture- and context-specific; non-formal knowledge; orally transmitted, and generally not documented; dynamic and adaptive; holistic in nature; [and] closely related to survival and subsistence for many people worldwide." Indigenous knowledge has also been described as "the local knowledge that is unique to a given culture or society … the basis for agriculture, health care, food preparation, education, environmental conservation, and a host of other activities

From another website (http://ctabobandung.files.wordpress.com/2011/11/ns-primer.pdf), we found the following definition of native science by Cajete (2000):

Native Science, which is also referred to as Aboriginal Science and IS, includes the "wide range of tribal processes of perceiving, thinking, acting, and 'coming to know' that have evolved through human experience with the natural world". It is one aspect of a broader body of IK and is characterized by the following traits:

- Holistic Native Scientific Knowledge includes knowledge of the metaphysical (spiritual) world and reflects a Native view of nature as interconnected and interdependent.
- Locally valid Native Science is rooted in local places and is often practiced to meet community needs for the long term survival of a people.
- Contextual Native Scientific Knowledge is derived through direct interaction with the natural world.
- Value-laden Native Science assumes responsibility for maintaining harmonious relationships among people, nature, all life, and the spiritual realm.

From a typical Eurocentric science point of view, it is tempting to think that IS is just part of the indigenous people's knowledge that deals with nature. However, such a simple classification overlooks the fact that, in most indigenous communities, there may not be appropriate words that correspond to knowledge and science. Pertaining to indigenous languages and cultures, concepts concerning knowledge and science are related to "ways of living" or "ways of living in nature" and involve "coming to know' in addition to a body of knowledge (Aikenhead & Ogawa, 2007). From such a perspective, there is no clear boundary between IK and IS because both terms refer to indigenous ways of living (in nature). Similarly, we may understand the relationships between IK and TEK along the same line. Concerning the use of terms, Hogg (2011) carried out a comprehensive review on the coherent use of the term "funds of knowledge (FoK)" within the literature, focusing on two key questions: What is the current scope of settings for FoK research? What do writers

mean when they talk about FoK? Hogg (2011) concluded in her review by saying:

> Arguably, findings of differences in researchers' definitions of FoK work relate to application of the concept in a variety of contexts. Just as a hybrid view of culture leads to the expectation of diverse findings, in my opinion it is unhelpful to force agreement on a single definition, which may be inappropriate for specific settings and purposes. (p. 673).

Realizing that IS/IK is a very complex concept which is intimately tied to the people, the place they live, their community, their culture, the way they live, the way they come to know nature, and their worldviews, various authors described and explained the distinctive features of IS in further detail and put efforts in making comparisons between the special features of IK and WMS. They also discussed the value and relevance of IK in science and mathematics instruction and explored ways to include IK in the science and mathematics curriculum (Aikenhead & Ogawa, 2007; Barnhardt & Kawagley, 2005; Battiste, 2002; Brayboy & Castagno, 2008; Hatcher, 2012; Irzik, 2001; Lewis & Aikenhead, 2001; McKinley, 2007; McKinley & Stewart, 2012; Quigley, 2009; Snively & Corsiglia, 2001). In fact, a recent book by Aikenhead & Michell (2011), aimed at supporting science teachers to implement science curricula with the inclusion of IK in a culturally responsive science classroom, has comprehensively discussed and summarized the discussions and debates on the issues around IK mentioned previously. While devoting a chapter to comparing the two ways of knowing nature, Aikenhead & Michell (2011) cautiously remind readers to avoid a number of pitfalls when comparing cultures, namely, stereotyping, language, and different versions of Eurocentric sciences. In this regard, it is worthwhile pointing out that, in this special issue, Luitel tried to compare the nature of mathematics as a body of pure knowledge to an alternative view. While the former gives rise to an exclusive emphasis on an ideology of singularity, epistemology of objectivism, language of universality, and logic of certainty, the alternative view of the nature of mathematics as an impure knowledge is discussed, along with its possible disempowering features, such as essentialism, hegemony, and dualisms.

Exploring Culturally Relevant Pedagogy

As we stated at the beginning of this introduction, national reforms in science and mathematics call for *all* students to become literate in mathematics and science. In response, state, province, and national curricula and standards in

mathematics and science are being developed; however, these curricula and standards often emphasize the commonality of what students are expected to learn in the name of establishing "high expectations" for all children while steadfastly ignoring the vast differences among students, schools, and communities (Levinson, 2012). Evident in this special issue is the fact that schools are still failing to meet the needs of indigenous learners in mathematics and science. We ask, therefore, how can we have science and mathematics *for all* unless we are inclusive of the science and mathematics *of all* (Taylor, 2013a, b)?

Research into the causes of the academic underperformance of indigenous students includes the differing epistemological and ontological underpinnings of IK production when compared to the production of WMS, the manner of typical science instruction, the nature of the indigenous learners, and the potentially colonizing influence of schooling itself.

Solutions have been posited to support indigenous students' academic success in mathematics and science. Culturally responsive curriculum has been suggested as one way to engage indigenous learners (Brayboy & Castagno, 2008). Belgarde, Mitchell & Arquero (2002) conceptualize culturally responsive curriculum as infusing the curriculum with rich connections to students' cultural and linguistic backgrounds within family and community contexts. Kuwahara, in her paper, explores how to operationalize culturally responsive curriculum with students with diverse ethnic backgrounds in Hawaii. She found that all students responded positively to a place-based, culturally oriented curriculum but in differing ways. Non-Hawaiian minority students responded more to the spiritual aspect of learning about place and Hawaiian culture. The self-identified Hawaiians that had enrolled in a Hawaiian Academy were motivated to learn science content more deeply as a way to care for their land.

Another way to engage indigenous students is to create "hybrid spaces" where IK and WMS can be explored (Baron & Tan, 2009). Huang and Lin, in their paper, found that Atayal students in Taiwan achieved a deeper understanding in mathematics when teachers bridged the students' knowledge and the ways of knowing of mathematics to the mathematical concepts.

To have a culturally responsive curriculum, there is a need for teachers to be culturally competent. Brayboy & Castagno (2008) describe the qualities of such teachers as respecting and using students' identities and backgrounds to create optimal learning, having high expectations for students, and ensuring those expectations are realized. However, there is a significant body of literature and evidence to suggest that nonindigenous teachers simply do not know enough about how to teach indigenous

children. Despite the best intentions and commitment from many nonindigenous teachers, most have inadequate understandings of appropriate pedagogies and the complexities of indigenous cultures, knowledge, and identities (Santoro, Reid, Crawford & Simpson, 2011; Brayboy & Maughan, 2009; Villegas, Neugebauer & Venegas, 2008). Nam, Roehrig, Kern and Reynolds, in their paper, show that even science teachers experienced in teaching in schools with large populations of indigenous students can face tremendous difficulties when trying to implement culturally relevant pedagogy into their classrooms.

Handa and Tippins, in their paper, suggest that cultural relevancy in preservice science teacher preparation may be supported in a "third space" in three ways: (a) recognition of prospective science teachers as generators of community FoK in contemporary time, (b) creation of critical and decolonizing pedagogies situated within the notion of place, and (c) expansion of official school science to accommodate knowledge from marginal spaces.

Even if teachers are prepared to teach indigenous learners, the larger world of science education, schooling, and assessment often does not support the strengths and learning resources of indigenous learners as shown in the paper by Grootenboer and Sullivan. Aboriginal students in Australia in their study often knew the mathematical concepts underlying the assessments but encountered difficulties in the format of the assessment and the contextual information used to frame the individual test items. Culturally responsive teachers can buffer some of the effects of nationalized assessments through the explicit messages they give their students. Middleton, Benson, and Tang, in their paper, found that Mayan teachers residing within the community they teach were able to support their students' identities as science learners through developing culturally responsive curriculum based upon their extensive knowledge of the children, the community, and the place. This special issue highlights the need to increase the number of science teachers who are indigenous while at the same time educating all science teachers to be culturally responsive before teaching science to indigenous children.

It appears that any approach to redress these issues will be as much about culture and social justice as it is about curriculum and pedagogy. Many indigenous students face "double segregation" of race and ethnicity and by class or even "triple segregation by race, class, and language (Orfield & Lee, 2006) in school. There is cultural capital gained through learning mainstream mathematics and science that is legitimized in its associated assessments. However, indigenous students are often denied access. Kidman, Yen, and Abrams' research supports the premise that

indigenous students need to learn science in the context of its historic, cultural, and political underpinnings of knowledge production so they can understand the implicit power narrative within scientific knowledge. From the papers included in this special issue, there is still a gap about how to teach mathematics and science so that indigenous students have the knowledge and skills to upend and reshape power relationship directly through public, political, and civic action.

Mixed Methods Research: Getting the Ingredients Right

As we reviewed papers submitted for this special issue, we were heartened to learn that researchers in many countries are deeply engaged in investigating how culturally relevant teaching can be generated for indigenous learners. However, we noted that a number of important methodological issues had not been addressed in numerous papers, particularly issues of ethics and epistemology. Was this due to poorly designed research or was it the way in which the studies had been narrowly represented for publication in a mainstream science education journal?

As we worked with authors, providing suggestions for improving their papers and reviewing subsequent drafts, it became clear that, in many cases, the objective authorial voice of the researcher was masking the context and process of the research, rendering invisible the cultural setting of indigenous communities in which the fieldwork had been conducted, the quality of researchers' relationships with indigenous participants, and the potential richness of qualitative data analyses. When we invited authors to add missing detail to their papers, many did so, yielding important insights into the ethical and epistemological dimensions of their research. Why were these details omitted in the first place, and why do we regard their inclusion as important?

In social science research, *mixed methods* research designs have become increasingly popular, with quantitative and qualitative methods being employed in varying ways for a range of purposes. No longer are we compelled to subscribe to a one-size-fits-all "scientific" methodology; instead, we can include qualitative methods that allow a special sensitivity to local context. Contemporary qualitative methods, especially those based on the *interpretive research paradigm*, are well-suited to ethnographic investigations aimed at understanding the culturally different other on his/her own terms, endeavoring to look at the world through his/her eyes. Interpretive research methods are regulated by numerous quality standards

associated with *intersubjectivity*, allowing researchers to portray the unique context and dynamic process of their inquiries, especially the emergence of their understanding of the "self–other" relationship, which Fine (1994) poetically described as "working the hyphen." The interpretive research paradigm, which we describe in more detail in the next section, differs significantly from the positivist paradigm that dominated conventional social science research for much of the twentieth century; an epistemology that is well-known for its quantitative methods and gold standard of *objectivity*.

Most science and mathematics educators are raised on a diet of objectivity and, as researchers, find it difficult, at least initially, to introduce intersubjectivity into their research repertoires. And so it seemed for numerous papers submitted to this special issue. Although many had employed mixed methods research designs, few had ensured that their qualitative methods adhered to intersubjectivity as the guiding light. Instead, objectivity appeared to have served as the chief regulator of nearly all aspects of their research, from design to fieldwork to analysis to report writing. Here, we discuss several important shortcomings of this approach and suggest how to avoid them in future mixed methods intercultural research.

But first, an important note. We use the term "intercultural" to signify that research is not "culture-free" (including conventional objectivist research) and that researchers who are cultural outsiders to a community they are investigating are inevitably immersed in their own multicultural worldviews. The interpretive research paradigm foregrounds the researcher's cultural situatedness and its role in shaping his/her relationship and interpretations of the culturally different other's worldview. There are various methods for recognizing and dealing with the inevitability of this intersubjectivity, all of which involve at least making it transparent.

Ethics

When objectivity rules implacably, the researcher's objective reporting voice—*third person*, *past tense*, *passive voice*—remains silent about his/her standpoint and stakeholding in the research, thereby masking possible conflicts of interest associated with his/her agenda. Contemporary research methods textbooks have a major focus on research ethics and articulate general ethical principles for guiding the design, conduct, and reporting of research. Chief among these are a commitment to *non-maleficence*, or avoidance of harm to research participants, and *beneficence*, or a commitment to making a positive contribution (e.g. Cohen, Manion, & Morrison, 2000). These guiding principles help to ensure that fieldwork is conducted ethically and are of particular

importance in regulating intercultural research, especially when cultural or community outsiders conduct fieldwork in indigenous communities.

Many universities and government agencies have rigorous ethical approval processes in place to protect indigenous communities from exploitation by (well-meaning) anthropologists, psychologists, ethnologists, and so on. It has been argued (Fatnowna & Pickett, 2002) that, historically, much research on indigenous peoples has been of greatest benefit to the careers of researchers themselves, with little benefit flowing to indigenous communities and, worse still, distinct disadvantages flowing from (eugenics-flavored) research that has reinforced cultural stereotypes of indigenous people as less "intelligent" and culturally and psychologically "in deficit" compared with Western normative standards. Politically astute leaders of indigenous communities are rightfully protective given the dark history of earlier research. But even in these more enlightened times, well-meaning outsider researchers need to be wary of embodying the conceit of paternalistic benevolence that serves (unwittingly perhaps) an invisible *neocolonial agenda* as discussed by Emilia Afonso, especially when they presume to speak on behalf of indigenous peoples, to label and categorize them and to take ownership of their IK in order to design culturally relevant curricula, publish this knowledge in career-enhancing journals (such as IJSME), or market it in the West as life-enhancing dietary supplements.

As research manuscript reviewers, we sought clarification from authors about the ethics of their mixed methods research designs by asking the following questions and we urge future researchers to address these questions explicitly in manuscripts they submit to journals: *In what way was the researcher well-qualified and experienced to conduct fieldwork in the indigenous community? How did the researcher establish entry to the site and ethically appropriate research relationships with the indigenous community? What is the researcher's history of affiliation with the community? Does she/he speak the local language? If not, how was culture sensitivity established? How did the researcher intend to benefit from the research and was there any possibility of a perceived conflict of interest in his/her stakeholding in the research? Does she/he have a moral standpoint based on, for example, cultural pluralism that motivates his/her involvement or is she/he a value-neutral disinterested observer (as implied by the objective voice of the research report)? Was the issue of ownership of the community's funds of knowledge negotiated? And did this involve negotiation over the authorship of subsequent research publications that reported this indigenous knowledge?*

Context

More often than not, a "rich and thick" qualitative description of the physical, social, economic, cultural, and linguistic features of indigenous communities was missing from the mixed methods research we reviewed. Although qualitative methods of interviewing had been employed, it was only the "bare empirical facts" that seemed to matter most. This seems to be a case of "methodolatry" (Janesick, 2000) wherein subservience to the imperatives of objectivity predetermines the rhetorical structure of the research report (in accordance with the scientific method) and the omnipotent (decontextualized, retrospective) voice of the reporting author. As we discuss later, qualitative methods embodying an interpretivist epistemology serve to produce deep local (rather than universal) understanding, and thus, a rich and thick ethnographic account of the research setting is a necessity.

We would ask: *Does the indigenous community have a tribal name or names? And what of the (changing and disputed) politics of naming? Should it be Black or black, White or white, Colored or colored? American Indian or Native American? Indigenous or indigenous? Australian Aborigine or Indigenous Australian or Yolngu/Nyoongar/Anangu Pitjatjantjara/etc.? Western or western? Who decided—the researcher or the community? What is the mother tongue(s) of the community? Did the community have a clearly articulated set of aspirations for the education of their children? How satisfied are they with the current school (state?) curriculum? Do they desire change to, for example, a bilingual curriculum that includes IKS/TEK? And, back to ethics, was there a conflict of interest between the community's curricular aspirations and the researcher's interests? Is so, how was it resolved; if not, whose agenda prevailed?*

Analysis

Slavish adherence to the rule of objectivity can also result in research participants being portrayed as objects of the inquiry rather than as empowered subjects of a collaborative venture. Extracts of interview transcripts that reduce participants' voices to a few disembodied words, yielding syntactical analysis stripped bare of the social context in which the recorded words were uttered, can mask the quality of the communicative relationship between participants and researcher. Where interview extracts are dominated by the researcher's voice with seemingly compliant participants providing simple affirmatory responses, the researcher can appear to be interviewing him/her(cultural)self, revealing

very little about the experiences, values, perceptions, or worldview of the culturally different other. The resultant *positivist* analysis produces an impoverished portrait of the indigenous culture, much like the shadows on the wall of Plato's cave.

We would ask: *Who conducted the interviews or tests—a cultural outsider or a trusted member of the local community? What language was used? Was a translator involved? If a local community person was engaged, was this an indigenous person and how were they trained for this role? How was adequate rapport established with respondents (especially children) to disclose their feelings and cultural beliefs? Did this involve "cultural border crossing" by either party, and how was the crossing facilitated? For example, to what extent was the researcher immersed as participant-observer in indigenous children's classroom activities and perhaps out-of-school lives? How was the familiar made unfamiliar? Was a clinical interview conducted or was it more like a "good conversation" (Kvale, 1996)? Was disconfirming evidence actively sought to challenge the researchers' a priori assumptions? Were "member checks" (Guba & Lincoln, 1989) performed to verify the researcher's subsequent interpretive validity? Were other data sources, such as participant observation, used to triangulate interpretive analyses?*

Enriching Intercultural Research Methods

Mixed methods research design is a promising approach for culture studies researchers, but its name can seriously mislead. Science and mathematics education researchers are accustomed to being directed by the foundations of their disciplinary history, and when that history privileges the gold standard of objectivity, it is understandable that qualitative methods are subordinated to quantitative research designs. This is not necessarily a bad thing, but, as we have discussed above, there are drawbacks for intercultural research: objectively written research reports mask more than they reveal and may result in the research appearing to be ethically questionable and epistemologically impoverished.

Qualitative research methods regulated by intersubjectivity, which make transparent the process and context of intercultural research, can go a long way to circumventing many of these concerns. So, can intersubjectivity be part of the mixed methods game? The short answer is, yes. But it requires ethical and epistemological astuteness. We believe that mixed methods research would be better labeled *multiparadigmatic* research in order that intercultural researchers can enjoy the full ethical and epistemological power of contemporary qualitative research methods.

We believe also that contemporary qualitative research can and should do much more to portray the richness and complexity of the culture (and language) of indigenous communities and of researchers' interactions with them. This is feasible because qualitative methods are no longer a handmaiden to conventional quantitative research. The field of qualitative research has developed enormously over the past 30 years and has generated powerful ethical and epistemological standpoints associated with the new paradigms of *interpretivism*, *criticalism*, and *postmodernism*, each of which carries its own quality standards for producing a distinctively different way of knowing, being in, and valuing the world. Detailed accounts of the theory and practice of multiparadigmatic research by indigenous and nonindigenous researchers can be found in Taylor, Taylor & Luitel (2012), Taylor (2013a, b), and Taylor & Wallace, (2007). A brief outline of the major characteristics follows.

Interpretive researchers are motivated by a quest for contextual understanding of the culturally different other, in accordance with an epistemology of intersubjectivity. They seek to understand deeply the other's values, beliefs, feelings, and worldview. They often write in a narrative voice to reveal an unfolding heartfelt understanding, thereby making the context and process of the research highly transparent. Their fieldwork observations of cultural activities, such as indigenous ways of living in natural and social environments, can be represented by vignettes supplemented by images, perhaps hyperlinks to audiovisual material residing on a website. By featuring cultural stories told in the voices of indigenous people, an *emic* (or insider) perspective is portrayed, thereby counterbalancing the researcher's *etic* (or outsider) perspective (Harris, 1976). Rich and thick (ethnographic) description enhances the *trustworthiness* of inferences drawn from the data, and standards of *authenticity* ensure that relationships with indigenous research participants are mutually empowering, educative, and ethical (Guba & Lincoln, 2005).

The paradigm of *postmodernism*, which promotes pluralism and difference, has ushered in *arts-based* research methods that employ alternative logics and genres (Knowles & Cole, 2008). These innovative methods enable artful ways of understanding and representing self and other and provide exciting means for portraying the complexity, paradoxes, ambiguity, and esthetics of social settings. A major goal is to engage the reader of a research report in pedagogical thoughtfulness and esthetic appreciation. A commitment to pluralism and difference can help the intercultural researcher avoid the trap of adopting an essentialist or static view of culture, be it Eastern, African, Western, or whatever, and to maintain skepticism towards the foundational claims of the grand

narratives of Western science and mathematics which reinforce the ascendency of the Western modern worldview.

Driven by ethical commitments to social justice and cultural sustainability, *critical paradigm researchers* work closely with indigenous collaborators to help deconstruct the powerful grip of oppressive ideologies embedded (often invisibly) in state-mandated curricula, especially curricula that position indigenous learners as cultural outsiders and their cultural identities and cultural capital as irrelevant to school-based science and mathematics education (Mutua & Swadener, 2004). Critical researchers adopt advocacy roles and work to empower indigenous learners as agents of sociopolitical change, helping indigenous communities to articulate and give public voice to their educational aspirations and needs.

Intercultural research that seeks to contribute to culturally relevant curricula can benefit greatly from indigenous researchers armed with epistemologies and ethics drawn from the new research paradigms. As cultural insiders, they can conduct uniquely insightful research that richly documents IKS, participate in designing ways of embedding IKS in local curricula, and work with community teachers to create hybrid curricula spaces and two-way border pedagogies that enable young indigenous people to develop multicultural identities and the ability to move readily between global and local communities.

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Eleanor Abrams

Department of Education
University of New Hampshire
Durham, NH 03824, USA
E-mail: eleanor.abrams@unh.edu

Peter Charles Taylor

Science and Mathematics Education Centre
Curtin University
Kent Street, Bentley, WA 6845, Australia

Chorng-Jee Guo

National Changhua University of Education
No.1, Jin-De Road, Changhua 500, Taiwan