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Indigenous Elementary Students' Science Instruction in Taiwan: Indigenous Knowledge and Western Science

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Abstract This preliminary ethnographic investigation focused on how Indigenous traditional wisdom can be incorporated into school science and what students learned as a result. Participants included community elders and knowledge keepers, as well as 4th grade (10-year-old) students, all of Amis ancestry, an Indigenous tribe in Taiwan. The students' non-Indigenous teacher played a central role in developing a science module 'Measuring Time' that combined Amis knowledge and Western science knowledge. The study identified two *cultural* worldview perspectives on time; for example, the place-based cyclical time held by the Amis, and the universal rectilinear time presupposed by scientists. Students' pre-instructional fragmented concepts from both knowledge systems became more informed and refined through their engagement in 'Measuring Time'. Students' increased interest and pride in their Amis culture were noted.

Keywords Worldview · Taiwanese Indigenous education · Indigenous knowledge

Introduction

Western science and technology have progressed rapidly since the Scientific Revolution of the 17th century, influenced by changes in Western culture. Today the scientific community's descriptions and explanations of natural phenomenon are taught in school science curricula worldwide, but often differ from those found in non-Western cultures.

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Cultural differences exist between East and West for Taiwanese students. The cultural gap is much wider for Indigenous[1] Taiwanese students, because they have to learn science through Chinese, rather than through their native language. In Canada, learning Western science meaningfully is considered to be a type of trans-cultural learning experience for Indigenous students (Snively and Corsiglia 2001). For Taiwanese Indigenous students it may even be called a double trans-cultural learning experience. It is partially for this reason that Indigenous students' school science achievement is in decline (Lin, et al. 2008).

Indigenous students understand nature through their own cultural experiences. Aikenhead (2001) pointed out that a small number of Indigenous students are able to integrate their own individual worldview with a Western scientific worldview, and consequently school science resonates with them. Their cultural adoption of Western science is not a problem. But for many Indigenous students, however, "enculturation into Western science is experienced as an attempt at assimilation into a foreign culture" (p. 338), which is similar to enculturation events experienced by many Indigenous students outside of school.

Our meaning of 'worldview' comes from Cobern (2000): 'A worldview refers to the culturally dependent, *implicit*, fundamental organization of the mind. This implicit organization is composed of presuppositions that predispose one to feel, think, and act in predictable patterns' (p. 8, original emphasis). Cobern (1996) also mentioned: 'Worldview provides a nonrational foundation for thought, emotion, and behaviour. Worldview provides a person with presuppositions about what the world is really like and what constitutes valid and important knowledge about the world' (p. 584). For instance, a science teacher who appreciates a student's worldview will likely anticipate that some ideas found in a science curriculum may appear plausible to the student, while others may not.

Conventional science teaching overemphasizes a scientific way of understanding nature by ignoring the worldviews of learners (Aikenhead 2006; Cobern 2000). Such teaching most often causes Indigenous students to resist the efforts of their teachers. As a consequence, there is an achievement gap between Indigenous students and their counterparts in mainstream society (McKinley 2007). People's relationships to the outside world are established through language, and language itself is crucial to one's worldview. For instance in the Australian Anangu Indigenous group, different languages or forms of writing convey different types of explanations to students (Russell and Russell 1999). Li (2004) pointed out that there are many differences between the grammar of Indigenous Taiwanese and the Chinese. These students often experience difficulties learning in a second language and in a classroom that conveys a worldview different from their own.

To improve Indigenous students' interest and understanding in school science, science educators have suggested examining the problem from the perspective of a student's Indigenous culture and how that local culture and the culture of Western science can complement each other in students' everyday world experiences (Aikenhead 2001; Chinn 2007; McKinley 2007). The preliminary study reported in this article shows how this suggestion can be implemented and provides evidence for the suggestion's viability.

A student's worldview will necessarily impact on how he or she will feel comfortable in a science class, and hence the degree to which he or she will feel motivated to understand the content presented (Cobern 2000). Currently in many non-Western nations, science curricula are imported from Western countries (Guo 2007). Some minor adjustments are made for the benefit of a country's *majority* groups. For instance, curriculum modifications

[1] We follow the United Nations' convention that the word 'Indigenous' encompasses worldwide the original inhabitants of a place (and their descendants) who have suffered colonization (McKinley 2007). 'Indigenous' therefore, includes the Aboriginal tribes of Taiwan.

in Taiwan include adding the scientific history of the majority Han ethnic group, and utilizing examples from city life to explain scientific principles. Few of these modifications, however, consider the life of *minority* groups such as Taiwan's Indigenous tribes or how their children might engage in meaningful learning in school science.

Most Indigenous families want their children to be well prepared to participate in Taiwan's mainstream society, but at the same time, they want their children to maintain their Indigenous identity, worldview, and tribal beliefs. This means that Indigenous students need to learn Western science as much as non-Indigenous Taiwanese students. To promote an equitable access to learning Western science, a balance must be reached in science classrooms of Indigenous students whereby their Indigenous way of understanding nature is both respected and explicitly acknowledged as classroom content, by its integration with the Western science content found in Taiwan's Indigenous classrooms (Aikenhead and Michell 2011; Russell and Russell 1999). Such a balance in elementary school science during a year of instruction might be about 10% Indigenous knowledge and 90% Western science knowledge in the curriculum.

To make this happen, teachers would first require a partial understanding of the cultural customs and worldview of an Indigenous people. Then teachers could begin to incorporate Indigenous knowledge into some of their science lessons, with the support of local elders and knowledge keepers. A teaching unit would *begin* by instruction that conforms to the worldviews of the students, making it much easier and quicker for these students to orient themselves within the learning environment of school science (Aikenhead 2001). Teachers would use examples and knowledge that students could more easily understand. As time goes on, students could learn more elaborate science content by building on earlier successes. Overall, there will be an appropriate balance between two complementary ways of understanding the local environment—Indigenous and scientific (Aikenhead and Michell 2011). Such curriculum materials could show how events can be dealt with by drawing upon Indigenous knowledge and Western science as appropriate.

Snively and Corsiglia (2001) suggested that a 'trans-cultural' science education would encourage a majority of people to draw upon scientific knowledge as needed, but it would not seek to force a Western cultural perspective upon non-Western people (i.e., no cultural assimilation). Science educators could help teachers form an open mind towards Indigenous knowledge so these teachers can help their Indigenous students begin to understand the relationships between their own Indigenous culture and the culture of Western science. Similarly, Aikenhead (2001) pointed out that the integration of Western science with Indigenous knowledge brings Western science to the attention of Indigenous students without asking them to adopt a Western scientific worldview. Teaching units must take into account the different cultural perspectives of the cultural group in question, and teaching materials need to be developed to suit that particular group because their knowledge is place-based, not universal.

If students engage in a trans-cultural science education, they may understand through participation and discussion the similarities between their own culture and the culture of Western science. From a constructionist perspective, students bring their past experiences into the classroom, and so students from different cultural backgrounds may interpret observations, evidence, and scientific concepts differently. Teachers must appreciate the cultural knowledge that students already possess, and then integrate some of it into their teaching. Such integration could encourage Taiwanese Indigenous students to learn more of their own culture, and it could also increase their appreciation of the knowledge held by Taiwanese tribes other than their own.

The wisdom of Indigenous knowledge is based on a sacred respect of nature, due mostly to Indigenous peoples' relationships and responsibilities toward nature (Knudtson and

Suzuki 1992). Thus, learning Indigenous knowledge may help children recognize this intimate connection between humans and nature.

The study reported here was a preliminary investigation into how an Indigenous culture and the culture of Western science might complement each other in students' everyday world experiences. A teaching module was developed for Grade 4 (10-year-old) students attending a predominantly Amis elementary school. The Amis tribe (population about 177,000) is the largest of 14 Indigenous tribes in Taiwan recognized by the government. The approximate 490,000 Indigenous people in Taiwan account for about 2% of the country's total population. Each Indigenous tribe has its own distinct language, cultural features, geographic location, traditional customs, and social structure.

The teaching module was revised from a science textbook unit 'Measuring Time' by combining with it Indigenous knowledge learned from elders—the wisdom of traditional Amis concerning time and its measurement. Ideas about time held by the Amis students were monitored before, during, and after the module was taught by their regular teacher. The study was primarily interested in documenting (1) Amis knowledge of time and its measurement, (2) students' pre-instruction knowledge related to Amis knowledge, and (3) what students learned from the trans-cultural module 'Measuring Time'.

Two topics are highly relevant to the context of this preliminary study: a cultural perspective on time, and the Amis tribe of Taiwan. These are summarized before presenting the study's methodology, results, and findings.

A Cultural Perspective on Time

The concept of time that scientists generally apply is *rectilinear time*—uniformly and limitlessly linear, calibrated by identical, mathematical, arbitrary units. The idea of rectilinear time was originally a Eurocentric culture-based concept. Bolter (1984) analyzed the concept of time held by ancient Greeks, by Europeans during their Middle Ages and Renaissance period, and by modern computer engineers. He concluded that a particular technology specific to each culture defined different concepts of time: the production of clay pots for ancient Greece, the mechanical clock for 14th century Europe, and perhaps the computer in the near future. Prior to mechanical clocks, time was, more or less, a subjective personal concept. The people of ancient Egypt and Greece, for instance, measured time by their experiences and their momentary needs (e.g., hunger and sleep). Experiences and needs were not regulated by the clock, as today. Efficiency or productivity (output per unit time) was not part of their worldview. Of interest to us here, however, is Bolter's thesis that the concept of rectilinear time was constructed as a result of the invention and public presentation of the mechanical clock.

A weight-driven clock first appeared in the public domain in Milan, Italy, about 1335 CE. Such clocks were displayed in cathedral towers throughout Europe for all to see and marvel. Later spring-driven clocks appeared in European society; and then in 17th century Netherlands, the pendulum-regulated clock was invented by Christian Huygens. This instrument greatly improved the accuracy of time measurement.

The impact of a mechanical clock on Renaissance thinking was dramatic. Quoting Bolter (1984):

> What kind of a universe did the clock suggest? A precise and ordered cosmos, for the clockwork divided time into arbitrary, mathematical units. It encouraged men [sic] to abstract and quantify their experience of time, and it was this process of abstraction that led to the creation of modern astronomy and physics in later centuries. (p. 27)

Thinking of the universe as a well ordered clock became an ontological metaphor that took hold with religious overtones. 'The clock made explicit a view of the universe that orthodox Christianity had been tacitly encouraging for centuries' (p. 27). A clock-like universe harmonized with the theology of a well ordered universe created by God, and thus, accessible to human reason: 'The search into nature could only result in the vindication of the [Christian] faith in rationality' (Whitehead 1967, p. 12). Bolter (1984) concluded, 'God had created the world but remained separate from it, and this sense of separation encouraged men [sic] to study that world in a detached…way. Gone was Plato's divine, living universe, and in its place was a divine clockwork' (p. 28).

Perhaps rectilinear time became essentialized when Sir Isaac Newton wrote in his 1687 *Principia*, 'Absolute, true, and mathematical time, of itself, and from its own nature, flows equably without relation to anything external' (Cajori 1962, vol. 1, p. 6). Here an abstraction (rectilinear time) has been transposed into reality, and most scientists today assume Newton's transposition. For them, rectilinear time is real, not a culture-based concept.

A number of techniques existed in antiquity to track the movement of the sun, moon, and stars (according to the cosmology of the culture), which resulted in a variety of technologies and related concepts of time, including: various calendars (time of year), sundials (time of day between sunrise and sunset), and water clocks or hourglasses (for keeping track of short discrete periods of time). These concepts of time should not be confused with the eternally flowing, exact units of rectilinear time. Calendars simply connected solar or lunar regularities with agricultural, administrative, and religious events. Sundials were unreliable because the length of an hour (defined by the Greeks as one-twelfth of daylight duration) would change seasonably, and because clouds would cause this technology to 'crash' (to use the computer vernacular). Peoples' observations of the sun's position in the sky were almost as reliable. Water clocks and hourglasses were associated with the duration of a specific event, such as how long one could speak in a court of law or at government gatherings. These two technologies limited the verbosity of a speaker and are associated with the concept of discrete arbitrary periods of time—*discrete time*.

According to Bolter (1984) time is culture-based and originally associated with certain technologies found within a culture. This perspective leads to a very different concept of time associated with cultures that are divergent from Western cultures, such as Indigenous cultures worldwide.

One alternative to rectilinear is *cyclical time* (Knudtson and Suzuki 1992), a concept that harmonizes with the myriad of cycles observed in nature (e.g., life cycles, celestial cycles, seasons, and daily cycles).

Indigenous scholar Ermine (1995) of the Cree First Nation in Canada reminds us that repetitive cycles in his Indigenous 'outer physical space' interact with cycles in 'inner spiritual space.' Therefore, some spiritual ceremonies connect with deceased generations (i.e., in 'inner space'). But these ceremonies must occur in harmony with specific events in a cycle of 'outer space' (the physical world). A person with a Western worldview might interpret such a happening as time travel into the past, but that interpretation comes through the lens of linear time. Through the lens of cyclical time, it is not time travel but a natural relationship in the web of interrelationships of existence presupposed by Indigenous ontologies.

Similar to other cultures that use the concept of discrete time, Indigenous cultures also consider time to be the space between two events. However, this space is much more than a numerical, *physical*, measured space of Western cultures (e.g., the time for an hourglass to empty). An Indigenous space of time between events also includes emotional, mental, and spiritual facets. Because relationships among everything in creation are fundamental to

Indigenous peoples, Indigenous time embraces physical, emotional, mental, and spiritual *relationships* associated with an event. Therefore, when deciding to begin an important meeting or a ceremony, for instance, elders will talk about 'when the time is right'. That is, an event should begin when the leaders sense that people are physically, emotionally, mentally, and spiritually in synchrony with the event; rather than deciding to start by looking at one's watch—the icon of rectilinear time. Indigenous epistemologies are predicated on cyclical time, while Western science epistemology usually presupposes rectilinear time.

The Amis Tribe of Taiwan

Taiwan is home to many ethnic groups, including 14 different Indigenous tribes of which the Amis tribe has the largest population (about 177,000). Its land base stretches along the plains around Mount Chilai in northern Hualien, south through to the long and narrow coastal plains and the hilly areas of Taitung and the Hengchun Peninsula of Pingtung. Like other Taiwanese tribes, the Amis have their own distinct language, cultural features, traditional customs, and social structure.

Their traditional social organization is based mainly on the matrilineal system. When marrying into the wife's family, the male must move into the wife's household residence. Family affairs including finance and property holdings are decided by the female head of household. Important affairs of the marriage or the allocation of wealth should be decided in a meeting with the uncles of the female household.

On the other hand, the public affairs involving the community in tribal politics, laws, warfare, religion, and ceremonies are dealt with by an institution consisting of a male leadership group comprised of different age ranks. The most important traditional ceremony is the Harvest Festival, which has rituals for celebrating the males entering their manhood and into a new age-ranking group (Council of Indigenous Peoples 2008).

The Amis community that participated in the research study is located on the east coast of Taiwan, surrounded on one side by mountains and on the other by the vast blue Pacific Ocean. The natural environment here has not undergone much damage. Much of the land is Indigenous protected land with rich animal and plant ecologies. Most villagers adhere to models of living that have existed in the region since ancient times. The cultivated land is also characteristically Indigenous. Except for the cultivation of rice and millet, the Amis people fish in the ocean or perform traditional Amis hunting rites in the mountains when the fields are fallow or when it is fishing season. Due to the demands of the environment, elders continue to be engaged in farming and fishing out of adherence to the Amis customs of their ancestors, despite their old age. Their cycles of work and rest coincide with those of nature, although their everyday work must provide them with the necessities for their survival.

Methodology

This preliminary ethnographic investigation adopted a naturalistic inquiry approach proposed by Lincoln and Guba (1985), and it was conducted by a classroom teacher and the first two authors. We sought to apply the viewpoints of Snively and Corsiglia (2001) concerning cross-cultural science education; that is, teachers need to interrogate and incorporate the prior beliefs of indigenous children, and teachers need to talk with children about multiple perspectives and traditions of science that encourages mutual respect as well as an appreciation for differing ways of knowing. Thus, the researchers helped a non-Indigenous teacher become more familiar with Indigenous values and knowledge of the Amis tribe. Collaboratively, the teacher and researchers acquired and developed written materials describing Indigenous worldviews. This content was vetted by interviewing local tribal elders and knowledge keepers to gain an understanding of the actual conditions under which these worldviews are manifested for the Amis people.

Research Context

Students The teaching module was developed in a fourth grade (10-year-olds) class of Amis students, consisting of six girls and six boys. They all grew up within their Indigenous tribe and are very familiar with its rituals and activities. A few students lived scattered throughout the agricultural fields or forests among the hills, but most lived in the local village. Most students were being raised by their grandparents, who completely trust and support the school and the teachers.

Teacher The non-Indigenous participating teacher, Jean (a pseudonym), has a master's degree in science education and had taught in this Indigenous school for 9 years. She was familiar with the customs and activities of the Amis and she personally identified with the village. Jean was the primary designer of the instructional module. The first two authors observed her teaching throughout the module's 12 sessions.

It is interesting to note how Jean's perspective altered somewhat over the last few years:

> Although I knew about the shortcomings in the school performance of Indigenous students, I didn't think about the impact of their culture. Since I entered the Graduate Institute of Science Education 2 years ago, however, I've gained a deeper understanding of Indigenous culture through discussions in both class and through my participation in research projects. I've started to think about the gaps that result from cultural differences. I've also come to notice the huge impact the parents' jobs have on the students. (Interview with Jean, 2007/01/05)

> In today's session of language class, we started on [the subject of] spring, introducing flowers that should bloom in the spring, including azaleas, chinaberry flowers and Paulownia, with which the students are familiar. The interesting thing is that the students here are actually unfamiliar with azaleas. It's hard to imagine! I therefore had to adjust my position quickly. I'm at an Indigenous school and I knew that they are familiar with betel nut flowers, *helicia formosana*, and shell ginger flowers! These kinds of science textbooks aren't suitable for them. (Reflective Journals by Jean, 2007/03/03)

School The school, located in the center of a village situated in a valley, has about 60 students of whom 90% are Indigenous. There is one class for each of the 6 grades.

Elders and Knowledge Keepers The first two authors' understanding of Amis traditional Indigenous knowledge was acquired through an inductive analysis of interviews. We utilized skills based upon Russell and Russell's (1999) method for understanding the differences between different ethnic groups. We performed qualitative comparative analysis between a summary of print materials gathered ahead of time and the content shared with us by elders and knowledge keepers during interviews. Thus, we began forging an understanding of Amis knowledge with respect to their conventional worldview in general, and their notions of time, specifically.

Two tribal elders and two retired Indigenous teachers (knowledge keepers) familiar with tribal life agreed to be interviewed after details of the project were clarified and discussed, including the roles of each researcher and participant. In Amis culture, such a verbal agreement is a binding commitment by all parties involved. Ceremonial gift giving was not appropriate in this Amis social context, although it is customary in some other Indigenous cultures worldwide. The two elders were a tribal chief and his wife. In the Amis tribe, the honor of being voted chief can belong only to an elder who grew up in the village (over a certain number of years). It is also necessary to understand the local habit, customs, and rituals. In the interviews, assisted by a translator due to the fact the elders spoke little Chinese (Mandarin), the Amis tribe's conceptions of measuring time were discussed. His wife helped her husband manage issues regarding the Amis people, such as preparing ritual activities in the community, and she performed agricultural work. She had a complete understanding of the regional culture and she had a good relationship with the younger members of the Amis tribe. During the interviews the chief did most of the talking.

The other two interviewees were retired senior elementary school teachers who also belonged to the local Amis tribe and had an understanding of the students' learning conditions. For this study, we relied more heavily on their knowledge of the local Amis culture.

The four informants of Amis knowledge were interviewed half the time by Jean (in keeping with ethnographic methodology) and the other half by the first two authors in tandem. In total, about five interviews occurred with the elders and about 14 interviews with the retired Indigenous teachers. Each interview usually took 30 min. We transcribed the audio tapes of the interviews and used these transcripts to analyze the data.

There are at least two approaches to combining an elder's Indigenous knowledge with Western science in a school context. Either way causes this Indigenous knowledge to be distorted by a non-Indigenous context into which it is placed. The first approach establishes an Indigenous framework into which Western science is infused (e.g., Aikenhead 2001). The second infuses Indigenous knowledge into a Western science curriculum (e.g., Aikenhead and Elliott 2010). The first approach has the advantage of conveying a less distorted view of Indigenous knowledge; but it has the distinct disadvantage of running the risk of being unacceptable to education authorities that promote scientific literacy in schools. Our preliminary study was consciously conducted in a political context that favored the second approach. This necessitated vigilance on our part in recognizing possible distortions to the validity of the Indigenous knowledge found in the instructional module. Our vigilance included a close, ongoing, working relationship with the retired Indigenous teachers to maximize the authenticity of the Amis Indigenous knowledge as much as humanly possible. Because our instructional module infused Indigenous knowledge into a specific unit in a Grade 4 science textbook, we used its topics of study (year, month, day, and discrete time periods) to organize the ideas about time expressed by the elders and knowledge keepers.

Although there are differences in time classification between scientific and Amis worldviews, similarities were also noted. In the 'Results' sections below, we report the Western science concepts first, followed by the Amis's perspective.

Instructional Module

The content taught in this study focused primarily on the 'Measuring Time' unit in the Grade 4 science textbook. The first two authors initially integrated the Amis ideas garnered from the elders and knowledge keepers. The module was divided into 12 sessions, about 40 min each, taught three times a week. This is the normal time allotment for the textbook unit. The teacher collected various types of materials and objects for measuring time to help teach the time-keeping methods of the Amis tribe. The following procedures were undertaken in designing and teaching the module (the two processes—designing and teaching—were often indistinguishable):

- interviewing Amis elders and knowledge keepers concerning the traditional topics of 'time', 'discrete bits of time', and 'time measurement';
- eliciting students' written responses during a pre-instruction class activity, in which open-ended questions were posed concerning the main ideas of the module;
- integrating Amis conceptions of time, discrete bits of time, and time measurement into the instruction module (described below);
- coming to know experientially different spans of time (a day, a month, and a year) by examining regular natural phenomena;
- coming to know the divisions and continuities in time by discussing the relations between days, months, and years;
- coming to know the standardized tools that ancient peoples used, such as incense sticks and hourglasses, to measure discrete amounts of time;
- understanding the evolution of time-keeping technologies and using time-keeping tools to learn to manage time.

While developing the module, the first two researchers held meetings with the teacher in person once every 2 weeks to discuss trans-cultural educational perspectives, as well as the design and implementation of the module. The two knowledge keepers were informally involved.

Jean motivated her students to discuss whether there were certain things that had to be done at a fixed time. For example, in the course of a year, which holidays occur on a fixed date? Which Amis celebrations occur at a fixed time? How can you know when that time is upon us? The teacher continued to develop the activity by asking students what tools they would use to help them determine those fixed times or dates, subsequently guiding them in thinking about how people of past times might have kept time. How might the Amis people of the past have kept time?

Throughout the module, activity worksheets were provided for students to perform experiments, make observations, and produce records. The students were sometimes asked to prepare for class by asking their parents whether the Amis tribe had any traditional tools for measuring time.

The module introduced time-keeping devices of ancient times to allow students to compare various ancient Amis time-keeping methods, identifying their differences and similarities during the course of the activity. Jean explained how a stick of incense, a cup of tea, or a meal could be used as discrete bits of time for ancient people, prior to the invention of tools for measuring discrete bits of time. This discussion focused students' attention on how the Amis tribe kept time traditionally.

Next, students were told the story of how the Dutch scientist Huygens in the 1600s constructed a pendulum to keep time. This gave students a chance to investigate how pendulums keep time. Then, Jean asked students to work together in designing their own crude time-keeping device and to compare it with other modern instruments. Afterwards, they were challenged by a time-management task that utilized the application of the time-keeping tools to a practical out-of-school context. A classroom discussion debriefed their application's success and generated evidence of their understanding of rectilinear time in an everyday situation.

Throughout the instructional module, we utilized other methods of assessment to understand the extent of student learning (e.g., Jean asked students to report on their time-keeping table; she collected each artifact along with the students' explanations attached; and she recorded the students' performance at operating the hourglass).

Overall, the instructional module approached the subject first through Indigenous experiential knowledge, and then through the introduction of knowledge taken from Western science and technology, thereby helping students better understand the complementary relationship between their own culture and Western science.

School Data Collection and Analysis

As mentioned above, the instructional module was taught over the course of 4 weeks, three times a week for a total of 12 sessions. Our data collection methods and the type of data collected were as follows:

1. *Interviews*: Following each teaching session, the first two authors took turns conducting open-ended interviews with students to understand three things: their original conceptions of time, what they had learned from the instructional module, and how the former affected the latter. At the same time, we made summaries of our unofficial and unscheduled interviews with the principal, teacher, and students. These unofficial conversations were spontaneous, unplanned, and free flowing, lacking time restrictions. It was not possible to record them electronically, as a result.
2. *Classroom Observation*: The first two authors were able to observe the entire teaching process aided by other teachers; for instance, they helped us with audio-visual recording during class time, and they participated in analytical discussions from time to time. After each class, we analyzed the session with the teacher and together made revisions to the module based on what we had discussed. Then we sketched out important ideas for the following class and organized its material.
3. *The Teacher's Reflective Journals*: Jean kept a reflective journal and wrote entries after every class. These included: events that had occurred during each science class, her ideas about teaching, what she felt students had achieved for themselves during the session, and the difficulties and discoveries she encountered. The journal also helped Jean and the first two authors reflect upon what the students had gained, and how Jean felt about those gains.
4. *Discussion Recordings*: The research group (comprised of the first two authors, Jean, and a few graduate students) met every 2 weeks. We discussed the relevant literature, shared our practical teaching experiences and the problems we had experienced during teaching, picked topics for activities, and discussed the problems we had in carrying out action research. The primary purposes were to collect statements from Jean, and to record relevant literature and teaching materials mentioned during the discussion.

A preliminary analysis of some of these data were performed immediately following each data collecting event. An outline summary of the main events was drawn up. An emerging research focus was identified. Relevant literature was then discussed to prepare for the next round of data collection. At the same time, the first-hand and preliminary analyzed data were coded and placed into various categories by using the constant comparison method (Strauss and Corbin 1998). Conclusions were drawn by using the methods of peer debriefing, triangulation (Cohen and Manion 1989), and member-, self- and auditor-checking. These processes speak to the credibility, dependability, and transferability that establish the trustworthiness of the findings (Guba 1981).

Results

The Amis Conceptions Related to Time

Although there is no precise synonym for 'time' in Amis traditional language, it is easy and natural for members of the Amis tribe to use regularly occurring phenomena in nature to keep track of what we call 'time'. Contemporary Amis people inherited the awe and gratitude their ancestors felt towards the earth's reoccurring phenomena.

Conception of 'Year' and 'Time Within a Year' The Amis tribe holds ritual celebrations as markers of time during a 'year'. Their '*miheca*' (year) is divided into 12 rituals, each associated with an interval of time (called a '*bolab*') characterized by weather and the state of the harvest.

> If the weather is chilly, then it means that the year of harvest is near. On the other hand, if the year of the harvest seems pretty hot, then it is time for the harvest festival. (Interview elders 20060313)

A *bolab* is not equivalent to a Western month. When each *bolab* is complete, the ritual is performed giving thanks for the peace and harvest granted to the Amis people. The elders have said that the rice harvest, which occurs twice in a *miheca*, is the most important standard for the Amis people in judging the time period of a *miheca*. Rice is the most important grain for Amis survival.

Apart from rice, the Amis people also judge time based upon the blooming and fruit-bearing patterns of commonly seen plants in the village. Chinaberry flowers and common reeds often provide some indication of time because they bloom and bear fruit only once a 'year', thereby giving the tribe an easy way to determine the coming of a new season. When the Chinaberry flowers bloom, the chief's wife knows with certainty that spring has come and that the busy agricultural season should begin. When the common reeds bloom, the Amis people know that autumn has begun. Through the course of the 'year', they tie knots on a string to keep track of the days; yet they supplement this record with observations of the weather. Nature's laws and cycles are revered standards in the Amis culture.

Amis concepts of time more associated with a Western 'month' are related to the phases of the moon. Because observing lunar phases is not always feasible due to weather, the Amis people also meticulously observe the tides to keep track of their 'lunar month'.

Their culture has commonly agreed-upon ways of determining a 'year'. This knowledge is passed from one generation to the next through oral tradition. Each generation learns how to make good use of the changes in nature and how to live in harmony with nature for their survival. For example:

> When the Chinaberry blossoms, then it is time for new leaves to grow. The second time it blossoms is during August. After the first harvest section of land is finished, it is time to start sowing the second section. The second section has not much time to rest. (Interview elders 20060317)

Conception of 'Time in a Day' The start of the day is determined through observations of natural phenomena occurring in close proximity to the home or work environment. These include the sounds of insects or domesticated birds. The elders, for instance, can determine time by viewing the shadows cast by buildings or plants, as well as by locating the position of the sun using their hands. Such positioning can give a fairly accurate idea of the time of day. When the sun is obscured, elders rely on the sounds of animals and insects to judge the time of day. For instance, when a certain animal makes a "lylylyly" sound, the elders know that it is approximately four o'clock in the morning and about time to get up. There are also the tiny cicadas whose sounds cover the mountain at about four o'clock in the afternoon each day, signaling that it is time to rest. Thus, the day usually began at four o'clock and ended soon after sunset.

In summary, the traditional Amis way of measuring time reflects a close relationship with nature. Their time is based on cyclic phenomena; hence, their time is cyclical (as opposed to Western science's rectilinear notion of time). The Amis people employ a combination of methods to judge time accurately and effectively.

Amis Students' Prior Conceptions of Time

Since students live in a modern Taiwanese society, they already have various different tools for keeping time. Therefore they are able, for the most part, to use different time-keeping tools, including clocks as well as solar and lunar calendars. Students can explain the scientific meaning of a year, a month, and a day, even if they do have some alternative conceptions about time measurement. In a classroom activity, we asked the students to think about how they might conceive of years, months, and days, supposing that they had no tools for keeping time. The students were divided into discussion groups and their ideas were recorded. Jean then used these data to probe the students further. Those results are summarized here.

Concepts of a 'Year' and 'Time Within a Year' Students understood that the course of a year was based on seasonal changes. In the spring, the trees sprout buds, lots of flowers bloom, small birds are in abundance, and the temperature is sometimes hot and sometimes cold. In the summer, the temperature is hotter, snakes are in abundance, and the cicadas call out loudly. In the autumn, the leaves turn yellow and fall, and the temperature begins to turn a little cold. In the winter, the temperature is very cold, days become windy, leaves on trees are scarce, and animals hibernate. It appears that these 10-year-old students judge the changing of seasons and the passing of a year through their own experiences with their natural environment.

Since the tribe is located at the mouth of a river, students were aware of large flocks passing overhead or stopping by the ocean during the changing of seasons. Over the past 2 years the same yellow-billed egret has been landing for several days in the school field looking for food while passing through. Thus, students have discovered that the appearance of certain birds can tell them something about the passing of the year.

Because there are a few Chinese banyan trees and maple trees in the schoolyard, the students have learned to judge the passing of the year based on their changes through the seasons. The two types of tree undergo changes at different times of the year.

From these data, we believe that students were highly conscious of the changes occurring in their surroundings and were able to use those changes to determine the time of the year, even without calendars or fancy watches.

Concepts of a 'Month' and 'Within a Month' In the previous school semester, students had observed the changing lunar phases over the course of a calendar month. Although students mentioned that they had observed flowers as a basis for judging the time within a 'month', they were unable, when pressed, to give reasonable explanations of how this process worked for them. Their way of thinking about 'months' continued to rely upon the lunar phases as a defining standard (i.e., their 'month' is a lunar month). The students' concept was less complex than the elders' concept of a 'month', which included tide information.

Concepts of a 'Day' and Time of Day, and Measurements of Discrete Bits of Time Most students neglected to think about nighttime as being part of a day—24 h. Their concept of day would seem to be restricted to daylight hours only. For instance, students had different standards for judging the beginning and end of a day, but all relied upon their personal experiences during daylight hours. Their perspectives are summarized as follows. For some students, a day begins with the sun rising out of the ocean in the east; then its position overhead indicates noon; and finally the day ends with the sun setting into the mountains. For many students, however, a day simply begins when the roosters crow, because these Amis students live in households that raise chickens. Students also expressed a series of judgments that relied on personal needs and responses of their own bodies; for example, waking in the morning constituted the start of the day while going to sleep marked its end.

Students had various ideas about judging the time of day. Some associated the morning with high tides and the afternoon with low tides. This oversimplification or misconception may have resulted from their experiences visiting the coast with their families, many of whom still make a living from fishing. Or their misconception may have arisen from what they had heard their parents and elders say about the ocean tides rising and falling. Again, the students neglected to think about what happens at night.

Students also talked about using their own shadows and the shadows of trees to judge whether it is morning, noon, or afternoon. They also determined how much time had passed during the day, by paying attention to the length of the shadows; dividing up the shadow's trajectory to understand the passing of time. For some students, this method was derived from their own experiences, while for others it had been learned from parents and elders. The students had also learned from their parents and elders that the cicadas cry each evening at about four or five o'clock.

Students were aware of measuring the passage of time (a discrete bit of time) by means of a water clock. This Indigenous technology was constructed using a very simple design. A hole is drilled through the bottom of a vessel, which is filled with water. By observing how long it takes for the dripping water to empty the vessel, a person can keep track of a discrete period of time. Students also knew that small markers could be drawn on the side of the vessel to further divide the discrete period of time into smaller intervals.

From the Amis students' pre-conceptions of time and its measurement, we know that they think of time in terms of natural changes and living experiences. Although their methods are not necessarily accurate in a scientific sense, they all closely connect students with nature in ways that are highly functional. It is apparent that students are able to use their experiences with nature to solve time-related problems, just as their ancestors did.

Students were able to pinpoint cyclical phenomena useful for telling time (e.g., within a 'day' a 'month', or a 'year'), including: the rising sun each day, the periodic appearance of the full moon, and the annual blooming of the *helicia formosana* and chinaberry flowers, which are often mentioned in their culture.

When we compared the Amis elders' interview data to the pre-instruction conceptions of the students, we discovered that the students' way of thinking about 'years', 'months', and 'days' have been shaped to a significant degree by their Amis culture (i.e., their thinking was learned from their parents and elders, for instance, they identified 4:00 to 5:00 pm by the cicadas cry each evening). Before studying the module 'Measuring Time', students' concepts were a combination of the elders' ideas (i.e., Indigenous knowledge) and the students' personal idiosyncratic ideas (i.e., their 'personal science'; Ogawa 1995), just like the previous stated concept of the rising and ebbing tides.

Impact of Amis Culture on Student Learning in 'Measuring Time'

While engaged in a 'Measuring Time' activity, students compared their own perspectives on time and its measurement (i.e., pre-instruction ideas) with those of their culture. They perceived a fairly close fit between the two. When asked why certain natural phenomena could be used as a basis for judging time, they recognized that these phenomena occurred with predictable regularity. This concept corresponds to cyclical time, a concept typically embraced by Indigenous peoples worldwide (Aikenhead and Ogawa 2007; Aikenhead and Michell 2011). These phenomena can also be interpreted by the Western science concept of periodicity. Moreover, we discovered that most students thought the Amis way of dealing with time was 'pretty cool', particularly the use of insect sounds and bird calls. By integrating Amis culture into the curriculum, the instructional module gave students more Amis examples of phenomena for telling time.

Students thought that observing nature carefully was a very convenient way of keeping time. However, they did not seem naturally curious about the Western scientific explanations for the observed regularity. In a worldview of cyclical time, periodicity is simply commonsense; thus, there is little need to explain it. This illustrates one impact of Amis culture of student learning.

Even so, students gained noticeably in their learning of Western science. On the one hand, they became more acquainted with the development of Western technology and scientific ideas related to time. They showed proficiency in comparing their practical activities of time-keeping methods and in using the science process skills of comparing, generalizing, and drawing on ratio relationships. On the other hand, their grades were much higher than in the past, according to their teacher's assessment records.

In the absence of an experimental control group, the improvements in students' abilities and achievement during this 'Measurement of Time' unit is based on the teacher's professional comparisons with similar students over the previous years using the same Western science activities.

Students were able to examine the different conceptions of time they had mentioned in class and were able to determine whether they could be used as a basis for keeping track of time (e.g., certain ceremonies and celebrations on particular days of the year, such as the fish-catching ceremony and the harvest festival). However, they later discovered that those dates could not be determined with certainty, not even with time-keeping devices. After students were taught that the 12 ceremonial sacrifices of the Amis tribe, which are used to judge the time of the year, corresponded to planting crops and the growth of plants, the students began to understand that the dates for the fish-catching ceremony and harvest festival were determined through the cycles of planting and harvesting they had experienced since childhood. The dates were scheduled alongside the sequence of different ceremonial sacrifices so that the fish-catching ceremony was closely linked with the natural arrival of the flying fish to their local environment. The harvest festival was connected to the ripening of rice crops. The ceremonies were not set by a predetermined date, but were designated by the natural progression of life, agriculture, and nature. The ceremonies were carried out according to these sequences of cyclical events.

Findings

Summary

With few time-keeping tools, the Amis people can rely almost completely on information garnered from nature when determining time, whether it is the time of the ‘year’, ‘month’, ‘day’ or another special time that is in question. The older Amis people are still in the habit of employing time-keeping methods inherited from their ancestors. Even when some of their methods of observing time prove to be insufficient (e.g., when a cloudy sky hides the phase of the moon), they are able to use other methods (e.g., observing the rise and fall of the ocean tides). Also, when the elders are working in the mountains, they are in the habit of determining with a high degree of accuracy when to return home by considering the length of their return journey alongside observations of weather, of light, and of the sounds of insects. Even though elders’ perspectives on time measurement conform to their observations of natural phenomena, only by understanding these phenomena as cyclical (periodic) can the observations be used to measure time.

These time-measurement methods reveal a keen awareness of nature, yet most Amis students in our study had not learned or had forgotten these inherited skills due to the encroachment of modern civilization. Following Aikenhead’s (2001) suggestion that teachers help students see their world from at least two different perspectives (Indigenous and Western) and since students can choose the one that better fulfills their goals at any given moment, appropriate teaching materials were developed to create the ‘Measuring Time’ module. It put students in touch with their cultural roots while learning Western scientific concepts of time and time measurement.

Decline of Amis Culture

Although references to animal sounds are abundant in Amis culture, students seem to know only about the cries of cicadas and little about particular bird sounds that can be heard at specific times in the mountains. Few Amis children today go into the mountains to help farm, and so most Amis children have little opportunity to learn this knowledge from family or elders.

Although we discovered in our research that Amis culture does influence students’ ideas regarding the measurement of time, this influence has been gradually decreasing, perhaps because the lives and habits of students in the 21st century differ from those of their family and elders. Even the elders had to express themselves in Chinese, and inevitably in the language of a non-Indigenous worldview. As a result, the Amis’s cultural inheritance tends to be modified, fragmented, or incomplete. For example, in an interview quoted above, an elder mentioned Chinaberry blossoms as a point of reference. She spoke about “the second time it blossoms,” a phrase which might suggest a linear concept of time. She did not speak in terms of the number of lunar or tidal cycles that occurred between the two blossoming events.

Looking Ahead

The worldviews of the teacher, the student, and what is reflected in the teaching materials are all latent and fundamental influences within science education. The worldview of the teacher plays an important role since he or she is in direct face-to-face communication with students. Because different nationalities have their own collective worldviews and ways of thinking, students' worldviews should be recognized as important to the classroom learning environment as the worldview reflected in a scientific textbook. The conventional extreme emphasis in school science on the worldview endemic to Western scientific knowledge can lead to the gradual loss of students' cultural identities in non-Western countries (Aikenhead 2006; Ogawa 1989).

A teacher like Jean may have a different cultural identity than her students, but if she can acquire an adequate understanding of the similarities and differences between her students' collective worldview and that of contemporary Western science, then she can view the students' collective worldview and their experiential knowledge as resources for academic achievement, rather than as a liability or disadvantage to their learning Western science—(the 'deficit model' of learning). This approach to teaching would involve treating Indigenous ways of knowing natural phenomena as something of value that coexist with scientific ways of knowing natural phenomena (Aikenhead and Michell 2011; Jegede and Okebukola 1991).

When students are exposed to different worldviews that embrace different explanations of natural phenomena, students tend to become more aware of their own worldviews. Moreover, by using Indigenous students' worldviews as a foundation for combining Indigenous knowledge and Western science in school science, teachers can motivate student interest and academic achievement.

Although the current decline of Amis culture is difficult to halt, the 'Measuring Time' module at least promotes student interest in learning and helps restore their cultural identity and pride. Although a cultural gap will continue to exist, we believe that students individually will adjust their innermost thoughts in ways that make sense to each student (Aikenhead and Jegede 1999).

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