SCIENCE LEARNING IN THE CONTEXTS OF CULTURE AND LANGUAGE PRACTICES: TAIWANESE PERSPECTIVE

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Abstract. This paper describes the cultural and linguistic practices in modern Taiwan and how these attributes and the current educational traditions and expectations influence students' science learning. Taiwan is a multicultural, not monocultural, country bound together by a common written language system. An examination of the traditional Chinese and indigenous cultural and language practices indicated that the habits of mind of traditional Chinese philosophers tend to be intuitive, metaphorical, descriptive, and holistic in contrast to the rational, causal, analytical, and reductive ways of thinking that are emphasized in western science. In addition, there are distinctive features of Chinese words and cultural beliefs that are likely to have impacts on students' learning of science. In view of the way science instruction is typically delivered in Taiwanese schools, implications of the above points on science education research and science instruction are also briefly mentioned.
Keywords: culture, language, science learning, Taiwan

Dutch
Samenvatting [Translated by Tanja Janssen]
In deze bijdrage worden de culturele en talige praktijken in het hedendaagse Taiwan beschreven en hoe deze en de heersende onderwijstradities en verwachtingen het leren van leerlingen op het gebied van "science" beïnvloeden. Taiwan is een multicultureel land dat bijeengehouden wordt door een gemeenschappelijke schriftelijke taal. Een beschouwing van de de traditioneel Chinese en inheemse culturele en talige praktijken heeft erop gewezen dat de denkpatronen van traditionele Chinese filosofen vooral intuïtief, metaforisch, decriptief en holistisch waren, in tegenstelling tot de rationele, causale, analytische en reductionistische manieren van denken die in de westerse wetenschap benadrukt worden. Bovendien hebben Chinese woorden en culturele opvattingen distinctieve kenmerken die waarschijnlijk van invloed zijn op het leren van "science" door leerlingen. De manier waarop "science" gewoonlijk onderwezen wordt op Taiwanese scholen, en de gevolgen van de bovengenoemde punten voor (onderzoek naar) "science" onderwijs worden eveneens kort aan de orde gesteld.
Keywords: cultuur, taal, leren van "science", Taiwan

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French
Résumé [Translated by Laurence Pasa]
Cet article décrit les pratiques culturelles et linguistiques à Taiwan et montre comment leurs caractéristiques, ainsi que les traditions et les attentes éducatives courantes influencent l'apprentissage des sciences par les élèves. Taiwan est un pays multiculturel, non monoculturel, fédéré par un système d'écriture commun. Un examen des pratiques culturelles et langagières chinoises et indigènes traditionnelles a montré que les habitudes spirituelles des philosophes chinois traditionnels tendent à être intuitives, métaphoriques, descriptives et holistiques, contrairement aux manières de penser raisonnables, causales, analytiques et réductrices, privilégiées par la science occidentale. De plus, des spécificités des mots chinois et des croyances culturelles sont susceptibles d'avoir des effets sur l'apprentissage des sciences par les élèves. En lien avec l'enseignement des sciences dans les écoles taiwanaises, les implications des points évoqués ci-dessus pour la recherche et l'enseignement des sciences sont aussi brièvement évoquées.
Mots-clés : culture, langage, apprentissage des sciences, Taiwan

Italian
Abstract. [Translated by Manuela Delfino]. Questo articolo descrive le pratiche culturali e linguistiche nella moderna Taiwan e come questi attributi e le tradizioni educative e le aspettative influenzino l'apprendimento delle scienze da parte degli studenti. Taiwan è un paese multiculturale, non monoculturale, unito al suo interno da una lingua scritta comune. Un'analisi del Cinese tradizionale e delle pratiche culturali e linguistiche indigene mostra che le abitudini mentali dei filosofi cinesi della tradizione tendono a essere intuitive, metaforiche, descrittive e olistiche, in contrasto con i modi di pensare razionali, basati su rapporti di causa-effetto, analitici e riduttivi enfatizzati dalla scienza occidentale. In più, ci sono caratteristiche distintive delle parole Cinesi e credenze culturali che sembrano avere un buon impatto sull'apprendimento delle scienze da parte degli studenti. Considerato il modo in cui la scienza viene normalmente insegnata nelle scuole di Taiwan, vengono anche brevemente citate le ricadute degli approcci sopra citati sulla ricerca in educazione e formazione scientifica.
Parole chiave: cultura, lingua, apprendimento delle scienze, Taiwan

Polish
Streszczenie Translated by Elzbiéta Awramiuk]
Niniejszy artykuł opisuje zwyczaje kulturowe i językowe we współczesnym Tajwanie oraz to, w jaki sposób te cechy i obecne edukacyjne tradycje i oczekiwania wpływają na uczenie się przedmiotów ścisłych przez uczniów. Tajwan jest krajem nie jedno-, ale wielokulturowym, związanym wspólnym systemem języka pisanego. Analiza tradycyjnych chińskich oraz lokalnych zwyczajów kulturowych i językowych świadczy o tym, że sposób myślenia tradycyjnych chińskich filozofów na ogół jest intuicyjny, metaforyczny, opisowy i holistyczny w przeciwieństwie do racjonalnych, przyczynowych, analitycznych, upraszczających sposobów myślenia, na które kładzie się nacisk w nauce zachodniej. Ponadto istnieją cechy charakterystyczne chińskich wyrazów i wierzeń kulturowych, które prawdopodobnie mają wpływ na uczenie się przedmiotów ścisłych. Wpływ wspomnianych wyżej obserwacji na nauczanie przedmiotów ścisłych oraz badania nad nim zostanie zwięźle scharakteryzowany z perspektywy typowego w tajwańskich szkołach nauczania przedmiotów ścisłych.
Słowa-klucze: kultura, język, uczenie się przedmiotów ścisłych, Tajwan

Portuguese
Resumo [Translated by Paulo Feytor Pinto]
Neste texto são descritas as práticas culturais e linguísticas na moderna Taiwan e o modo como estes aspectos e como a expectativas e tradições educativas actuais influenciam as aprendizagens científicas dos estudantes. Taiwan é um país multicultural tornado coeso pela partilha de um sistema de escrita comum. A análise das práticas culturais e linguísticas tradicionais, indígenas e chinesas, mostra que os hábitos intelectuais dos filósofos tradicionais chineses tendem a ser intuitivos, metafóricos, descritivos e holísticos em contraste com os modos de pensar racionais, causais, analíticos e redutores que são enfatizados pela ciência ocidental. Além disso, há ainda características das palavras chinesas e das crenças culturais que podem influenciar a aprendizagem das ciências. Perante a forma como a educação científica é tipicamente desenvolvida em Taiwan, são brevemente mencionadas as implicações dos aspectos acima referidos na investigação sobre educação científica.
Palavras-chave: cultura, língua, aprendizagem científica, Taiwan

Spanish
Resumen. [Translated into Spanish by Cintia Ortiz from Benemérita Escuela Normal Veracruzana, Mexico].
El aprendizaje de las ciencias en el contexto de las prácticas culturales y lingüísticas: una perspectiva taiwanesas.
Este estudio describe las prácticas culturales y lingüísticas en el moderno Taiwan y analiza cómo estas prácticas y las actuales tendencias educativas influencian el aprendizaje de las Ciencias en los estudiantes. Taiwan no es un país monocultural, sino multicultural, unido bajo un sistema común de lengua escrita. Un análisis del chino tradicional y de las prácticas culturales y lingüísticas indígenas indica que las formas de pensamiento de los filósofos tradicionales chinos tendían a ser intuitivas, metafóricas, descriptivas y holísticas, en contraste con las formas de pensamiento racional, causal, analítico y reductivo que se enfatizan en las Ciencias en occidente. Además existen rasgos distintivos en la lengua china y creencias culturales que posiblemente impacten el modo en que los estudiantes aprenden las Ciencias. Considerando la forma en que comúnmente la enseñanza de las Ciencias se da en las escuelas taiwanesas, este estudio brevemente analiza las implicaciones de los aspectos arriba mencionados que tienen relación con la investigación de la educación en Ciencias y la enseñanza de las Ciencias.
Palabras clave: cultura, lenguaje, aprendizajes de las Ciencias, Taiwan.

1. INTRODUCTION

Life in contemporary Taiwanese society is influenced by traditional Chinese and indigenous cultures and western culture, the latter especially in terms of science, technology, economy, and consumer products. However, science teaching in Taiwan typically presents western science to students without taking into account traditional cultural values, cultural beliefs, and the accompanying language practices. As competition to enter prestigious secondary schools and universities is a major concern for secondary school students, and many of their parents and teachers alike, the purpose for studying science is often reduced to passing tests and examinations. School science instruction emphasizes mainly western science. Contemporary and local issues are included in school science instruction, but traditional cultural and linguistic practices tend to be left out. Most students and the general public do not use the science concepts and process skills taught at schools to discuss science and technology related issues, to make daily life decisions, and to solve daily life problems. There is a wide gap between the intended goals of science education and students' and parents' conceptions and expectations about science learning. In addition, the languages used at home (L1) and in instruction (L2) carry with them some cultural values and beliefs about nature that may interfere with students' learning the language of science (L3). Since there are still relatively few research studies in this area, it is the purpose of this article to explore the potential culture and language barriers that Taiwanese students may have to overcome when learning science. Implications for research and instruction in science will be briefly discussed.

2. CULTURAL DIVERSITY

Taiwan has a population of approximately 23 million and a population density of 630 persons per sq. km **(**Government Information Office [GIO], 2005**).** To the external perspective, Taiwan may be viewed as a monoculture; but in reality, this small geographic nation with a high population density is made up of several cultures and has become more culturally diverse in recent times with a common written lan-

guage. Taiwan is dominated by the Han majority (96% of the total population) and other minority ethnic groups, including recent immigrants from South Asia countries and indigenous people (each group contributes approximately 2% to the total population). Major groups of Han people include mainstream Taiwanese and immigrants from mainland China after the 1949 retreat. Ancestors of mainstream Taiwanese (about 85% of the total population) came from southern parts of mainland China a few centuries ago, and they are composed of two subgroups: the majority Southern Fujienese and the minority Hakka. The Southern Fujienese and the Hakka speak different dialects of the Mandarin language and identify with their place of origin in China.

The immigrants from mainland China after the 1949 retreat are referred to as the Mainlanders, and they comprise about 11% of the total population in Taiwan. A great majority of Mainlanders came from all parts of China and are Han people of numerous cultural backgrounds who speak various dialects of the Mandarin language. Religious connections for the Han people are dominated by ancestor worship, Buddhism, and Taoism. However, western religions – mainly Protestantism and Catholicism – have converts among the various ethnic groups **(**GIO, 2005).

There are small numbers of Mongolians and Tibetans, who came to Taiwan after 1949. In addition, minority groups also include new female immigrants (known as foreign brides). Marriages between Taiwan and foreign nationals from China, Vietnam, Indonesia, and Thailand have increased since the late 1990s. In 2003, they accounted for 1 in every 3.1 marriages; and these marriages provided 13.4% of all babies born.

Less well-known minority groups of indigenous peoples that preceded the Hans migration to Taiwan are located over various parts of the island. There are currently 13 major indigenous peoples recognized in Taiwan: Amis, Atayal, Bunun, Kavalan, Paiwan, Pinuyumayan or Punuyumayan, Rukai, Sahizaya, Saisiyat, Thao, Truku, Tsou, and Yami. There are another 11 aboriginal tribes (Babuza, Basay, Hoanya, Ketagalan, Luilang, Pazeh/Kaxabu, Popora, Qauqaut, Siraya, Taokas, and Trobiawan) not recognized by the Taiwanese government; as such, they do not enjoy official language and cultural status and specific financial advantages (http://en.wikipedia.org/wiki/Taiwanese_aborigines). They differ in where they live, the language they speak, the ways they live, the tribal structure, the inheritance system, and other sociocultural and religious practices. Their ancestors also appear to have come to Taiwan at different times, with the Yami arriving less than 500 years ago, the Saisiyat about 6,500 years ago, and the other groups somewhere in between. The archaeological, genetic, and linguistic evidence suggests that these indigenous peoples belong to the Austronesian (formerly the Malayo-Polynesian) group, which inhabits an area of oceans and islands that extends from Easter Island in the east to Madagascar in the west and from New Zealand in the south to Taiwan in the north. The indigenous people's hometowns are located mainly in the central and eastern mountain areas. However, at least one-third of the indigenous people leave their home regions to work in cities, such as Taipei and Kaohsiung. Many indigenous parents leave their children to be cared for by elderly relatives in the mountainous areas while they seek employment in the cities. This practice results in the traditional values, beliefs, crafts, and knowledge being passed on to younger generations

by the elders. But some tribes find their indigenous languages (L1) at risk in this setting, and they rely on schools and public agencies to restore, conserve, and transmit their languages.

Unique cultural customs of Taiwan's indigenous groups – such as building houses on stilts to protect against damp, insects, and snakes; slash-and-burn farming; bamboo and rattan weaving; making clothing with animal hides; tattooing; chewing betel nuts; circle-dancing – distinguish the individual cultures. Despite exposure to Han, Japanese, and western influences, these indigenous groups have maintained much of their unique heritage, technologies, and beliefs about nature and naturally occurring events.

Under the compulsory educational systems in the Japanese ruling period (1895–1945) and the government of the Republic of China (ROC, 1949–), indigenous students, who speak a variety of dialects, have had to learn to speak and write in the dominant L2 languages (Mandarin and Japanese) in school. When visiting indigenous villages, it is often found that elderly indigenous people in their seventies tend to speak Japanese more fluently than Chinese and would prefer to do so when talking to people of another ethnicity. Indigenous people who are less than sixty years of age communicate with mainstream Han people using either Chinese or the Southern Fujienese dialect. Many differences in the cultural characteristics amongst the indigenous groups are based on traditional geographic distributions; and these experiences, values, and beliefs are part of the students' prior knowledge on which to base formal learning. It is important to note that cultural values, beliefs, ontological assumptions, epistemological views, and language practices in Taiwan are constantly evolving in response to various external and internal forces – strong western influences in democracy, science, technology, education, and economy. However, traditional knowledge, thoughts, and culture also play important roles on how people think and behave (Huang & Yore, 2003). Great efforts have been made in recent years to improve the quality of life and quality of education for the indigenous people by subsidizing indigenous families for their children's educational expenses, providing remedial classes, and providing more favorable conditions for them to enter secondary schools, colleges, and universities.

3. CULTURAL ASPECTS OF SCIENCE LEARNING IN TAIWAN

The social and cultural contexts within which western science originated and proliferated are very different from what one would find in the Chinese society. Although most people are aware of the important roles scientific knowledge and technological advancement play in their daily lives, they tend not to adopt scientific ways of thinking in dealing with personal and public affairs. In a sense, science does not play an important role in Taiwanese culture. In fact, cultural aspects of science manifest in the Taiwanese society, and more broadly and historically in Chinese society, mainly through one's personal observation and experience with nature. The specific influences of language and culture on conceptions about nature and naturally occurring events are the central focus of the National Science Concept Learning Study (Chiu, Guo, & Treagust, 2007). Chiu (2007: 442 & 445) stated:

> The most impressive finding was the Chinese characters that, on the one hand, served to facilitate student understanding of the nature of chemistry (such as acid rain implies acidity or the Chinese character with 金 "gold"), and on the other hand, had a detrimental effect on students' conceptualisation (such as carbon hydrate with 酸, acid in Chinese). Even the same character (酸) represented a different nature of matter.

Yen, Yao, and Mintzes (2007: 547) illustrated the beneficial effects of the blended character for penguin indicating it was a bird (鳥) and the negative effects for octopus and whale having a blended character including fish (魚). Kao (2007: 552) illustrated that non-aboriginal students outperformed aboriginal students on some questions related to the biological sciences.

Traditional cultural beliefs about nature and naturally occurring events are embedded in many Chinese sayings and proverbs, which are influenced by traditional Chinese philosophers, such as Confucius and Lao-Tzu. While order and discipline in human society are emphasized by Confucianism, unity and harmony of human beings with the surrounding nature are advocated by Taoism. The combined traditional Chinese worldview is that there is order in the constituent parts of the universe and that nature proceeds with regularity based on certain general principles. The organization, order, and operating principles of human society are assumed to be the same as nature; it is emphasized that nature is our mentor and that human beings should learn from nature. In the words of Lao-Tzu: "For I am abstracted from the world, the world from nature, nature from the Way, and the Way from what is beneath abstraction" (Merel, 1995). With such a worldview, it is interesting to note that although there are detailed descriptions of nature and naturally occurring events, including the observation of supernova and written records of about 40 repeated visits of Halley 's Comet, there were no theoretical attempts in traditional Chinese history to explain the workings, mechanisms, and occurrence of natural events.

It is also interesting to note that part of the western scientific worldview presumes that things and events in the universe occur in consistent patterns that are comprehensible through careful, systematic study and can be explained by physical causality. Scientists believe that through the use of the intellect and with the aid of instruments that extend the senses people can discover patterns in all of nature (American Association for the Advancement of Science, 1989). In contrast, the dominant, traditional Chinese worldview focuses only on the fact that the universe occurs in consistent patterns.

In view of the contrasts between the traditional Chinese worldview and the western worldview, it is worthwhile mentioning a report about Richard Nisbett's work entitled "The geography of thought: How culture colors the way the mind works", in which he says:

> East Asian thought tends to be more holistic. … Holistic approaches attend to the entire field, and make relatively little use of categories and formal logic. They also emphasize change, and they recognize contradiction and the need for multiple perspectives, searching for the 'Middle Way' between opposing propositions. … Westerners are more analytic, paying attention primarily to the object and the categories to which it belongs and using rules, including formal logic, to explain and predict its behavior. (http://www.umich.edu/news/Releases/2003/Feb03/r022703a.html)

Many metaphorical expressions in the form of idioms and proverbs exist in Mandarin to illustrate some of the points mentioned above; for example:

- Just as heavenly bodies keep moving steadily; man ought to be independent and be strong.
- Just as there are unpredictable storms and rains; we may run into fortunate or unfortunate incidents in our daily life.

The metaphorical nature of these expressions is in contrast to the causal relationship emphasized in western science. In addition, rather than reasoning on a clear causal basis, many Chinese proverbs are based on associations or contrasts in order to make certain points. A few examples are given below, with brief English interpretations and comments provided by the author.

- *Those who follow the way of nature flourish; those who go against it perish.* This suggests that one ought to follow the will of God, to do according to the way of nature, and to accept what comes naturally.
- *It is comparatively easy for changes in the shapes and forms of mountains to take place; it is much harder trying to alter one's disposition.* Personal traits and habitual frame of mind are hard to change. It is noteworthy here that human nature is compared to physical qualities of the natural world on equal backgrounds.
- *When the corner stones appear to be damp, then it will rain.* Here it is noted that the two events mentioned are highly correlated. They are connected by factual association rather than by causal relationship. The relationship is described, but the cause is not given. The scientific explanation that the humidity in the air is so high that water vapors condense into water droplets is not in the picture.

Many Chinese idioms and proverbs describe or relate to natural events and phenomena; for example, The light breeze comes in so slowly that it causes no ripples on the water. Regardless of how high the tree is, falling leaves from the treetop eventually gather around its root. In fact, the properties of light and sound had been studied and documented in some detail long before western science was introduced. Although technical applications of traditional knowledge in the fields of architecture, medicine, musical instruments, and astronomical observations have been well documented, theoretical models and explanations for natural events and phenomena were rarely if ever attempted.

Clearly, the habits of mind of the Chinese people as reflected from their use of words in Mandarin and other closely related dialects are very different from what is implied in the western scientific worldview. While the former tends to be intuitive, metaphorical, descriptive, and holistic, the latter emphasizes rational, causal, analytical, and reductive thinking. Traditional Chinese knowledge in the fields of astronomy, medicine, architecture, and other areas were developed based on careful observation and recordings of naturally occurring events and other phenomena associated with the material world around us. Certain theoretical explanations of the phenomena were attempted in terms of speculations about the balance of two broad constructs – Ying and Yang, respectively representing female and male constituent parts of the material as well as the spiritual world. Instead of carrying out controlled experiments and looking at data and warrants in order to test a hypothesis and make

a rational argument, some traditional philosophers used thought experiments and parables to establish their philosophical assertions. For instance, Chuang-Tzu, an ancient Chinese philosopher, put forward a thought experiment: *Given a meter stick, cut it into half each day; it will not stop even after tens of thousands of years*.

It is worthwhile mentioning that most scientists, educators, and teachers in Taiwan are educated under an educational system strongly influenced by western culture. They are accustomed to western ways of thinking and may not be aware of its difference from traditional Chinese ways of thinking. However, for most people the influence of western ways of thinking is often restricted to academic studies and professional works only. While it is a common practice to criticize, argue, and debate in scientific and academic activities, to do so publicly on other occasions might be considered as disrespectful and confrontational, especially by elders and higher-ranking colleagues. Therefore, in Taiwanese society, to seek objective, cold hard arguments – claims, evidence, backing, warrants, counterclaims and rebuttals, which is highly valued in traditional western scientific communities, is mingled with the subjective feelings to be polite and respectful. If cultural practices and values continue as noted above, there may be significant conflicts between the patriarchal, hierarchical Chinese culture and the individualistic, competitive cultural values embedded in western science.

4. LANGUAGE PRACTICES AND CULTURAL BELIEFS RELATED TO BORDER CROSSING

The official language of instruction (L2) at elementary and secondary schools is standard Mandarin. However, besides standard Mandarin, a number of dialects (L1) are spoken at home. Except for a small number of indigenous people, the non-standard dialects spoke by a majority of Taiwanese are very closely related to standard Mandarin. Although there are words and expressions that cannot be directly translated or related, most of the written words are the same; and the grammar is nearly the same. Many people in Taiwan can speak or understand both standard Mandarin and one of its variant dialects. Although some TV programs and news broadcasting are in non-standard dialects, most mass media are delivered to the public through standard Mandarin. Therefore, the language of instruction (L2) overlaps and in fact dominates the language used at home (L1) for the majority of students in Taiwan. Although there are problems associated with crossing the border from L1 (non-standard dialects) to L2 (standard Mandarin), the linguistic concerns – but not the subtexts of cultural values and beliefs – are often dealt with when students enter kindergarten or at lower grades of elementary school. The L1-L2 transitions present few difficulties for students at later stages. It is the border crossing from L2 to L3 (i.e., from the language of instruction to the language of science) that may result in learning difficulties for students at secondary school and college levels. At the secondary school level, science textbooks are written and taught in Mandarin. However, some science textbooks used at the college level are written in English while the courses are taught typically in Mandarin. The problems associated with the border crossing from L2 to L3 are different for secondary school and college students. The

following discussion will be restricted to practices and features related to border crossing between L2 and L3 primarily for secondary school students when learning science.

4.1 Characteristics of The Chinese Language System

A number of studies focusing on problems along this line have been carried out in Taiwan in recent years. Most of these studies dealt with distinctive features of Chinese written words that bear important impacts on students learning science, including:

1) Each Chinese character is often composed of some conventionally recognizable radicals that signify something important pertaining to the word. For instance, 火: fire, for something that has to do with fire or burning; 木: tree or wood, for all kinds of trees and things that are made of wooden materials.
2) Each character has its own meaning. Sometimes the same word may have a different meaning under different circumstances. Many terms are made of compound words – mostly with two characters. The meanings of the constituent characters usually provide a concise and vivid description of the meaning of the resulting term.

Although the above features of the Chinese written language may be helpful for science teaching and learning, there are related problems that call for particular attention. The fact that each Chinese character is composed of some conventionally recognizable radicals comes in handy when naming all the elements in the Periodic Table. The radical that is used for a particular element can easily identify elements in gaseous and liquid states under normal conditions; for instance, 氫: hydrogen; 氦: helium; 溴: bromine; 汞: mercury. Metallic solids and insulators carry radicals 金 and 石; for instance, 銀: silver; 鋁: aluminum; 碳: carbon; 硫: sulfur. Semiconductors are exceptional cases, of course.

Classification schemes used in biology also involve the same features yet with more notable exceptions. Radicals such as 魚 and 虫 are used to signify that they refer to fish and insect, respectively. Exceptional cases include the classification of mammals such as whale (鯨) and bat (蝙蝠) mistakenly belonging to fish and insect, respectively. Words for frog (蛙) and tadpole (蝌蚪) may be also confusing to students. Yen, Yao, and Chiu (2004) reported that a significant portion (ranging from approximately 35 to 95%) of Grades 4, 6, 8, and 10 students incorrectly classified earthworm, snail, and cricket as reptiles. Although they do not specifically point out the reason for such mistakes, it very likely has something to do with the fact that earthworm (蚯蚓), snail (蝸牛), and cricket (蟋蟀) contain the radical 虫, which is a simplified version of 蟲 that appears as a key word for reptile (爬蟲類) in Chinese. The radical 玉 is generally meant for things that have something to do with jade. Its

unusual association with coral (珊瑚) and rose (玫瑰), respectively belonging to animal and to plant, would suggest that there are interesting historical reasons underlying these connections.

Many compound words are used in Chinese for the naming of flowers, plants, animals, heavenly bodies, naturally occurring events, etc. They are also extensively used in terms for concepts, laws, and principles, such as temperature, distance, chemistry, chemical reaction, heredity, perspiration, law of causality, principle of conservation of energy, and so on. As mentioned earlier, many compound words in Chinese are capable of expressing the essential meaning of a given term or concept adequately; for instance, 地球: earth, ground as a sphere; 物理: physics, principles followed by objects; 動物: animal, moving creature;溫度: temperature, a measure of hotness; 長度: length, a measure of length; 電荷: charge, carrier for electricity; 擴散: diffusion, spreading out to a much larger region. On the other hand, misconception or confusion may arise because science concepts and terms are well defined and may not always be handled so easily. Wang (2004: 152) reported that a common mistake occurs for students at various grades from 4 to 11 in her study in thinking that *Plant has root hairs (根毛) that absorb water through capillary action (毛細作用).* Students apparently associated root hairs with capillary action through the Chinese character 毛 that appears in both terms.

There are words commonly used in L1 and L2 that are also used as well-defined terms in L3. In many cases, they refer to the same things or concepts. However, there are cases (e.g., energy, horsepower, and pressure that are respectively translated as 能量, 馬力, and 壓力) where the meaning of the terms cannot be precisely or correctly inferred by the meaning of each individual word. Many compound words involve force or work in L1 and L2, which have nothing to do with the kind of force or work defined in physics textbooks. Confusions and misconceptions may arise if teachers do not remind students specifically of the differences in the usage of such words in L1, L2, and L3. There are some L1 and L2 expressions in Chinese that may result in students' misconceptions about certain naturally occurring events, for instance, sunset, sunrise, falling frost, gaining rust, suck in. Units named after scientists are often translated into words that sound more or less the same in Chinese, and they would appear meaningless or very funny if interpreted literally. For instance, the translation for *Joule* literally means *burnt-out ear*. There are cases in which the Chinese translation matches the English term semantically and phonetically; for instance, 基因: gene, fundamental factor; 維他命: vitamin, maintaining one's life. Of course, there are special terms for more advanced topics or abstract concepts introduced in every branch of science that are hard to understand and difficult to translate into Chinese. Some new words have been created to serve that purpose. For instance, a new character with two radicals, one standing for fire and the other for quotient, has been created to represent entropy. Many professors and scien-

tists prefer to use scientific terms in English when they are engaged in conversation about scientific matters. This is also the case in science classes at the university level, where professors deliver their lectures mostly in Chinese but will use English terms from time to time.

4.2 Language Subtext – Cultural Beliefs

Kao (2007) explored aboriginal and urban junior secondary school students' conceptions of respiration. She found that aboriginal students demonstrated somewhat lower levels of understanding than their urban peers, but:

> both aboriginal and urban students held common alternative conceptions of respiration. … [They] have difficulty in grasping respiration as a chemical process rather than a physical one involving gases going into or out of organisms. … Furthermore, due to different living environments, the sources of these alternative conceptions for the two groups are somewhat different. Aboriginal students tend to learn knowledge in connection with natural phenomena or from their own experiences. However, urban students tend to learn knowledge in connection with common modern equipment and everyday appliances. (517)

Lee, Chang, and Yen (2007) found that the people of the east coast mountains demonstrated a unique conception of combustion that has fire as the vector of illness and disease agents. These indigenous people conserved fuel by having community firepits where they warmed themselves as a group during cold mountain evenings. The potential for transmission of communicable disease during such group activities has been ascribed a causal status within their conception of combustion.

In spite of the important roles language and prior knowledge play in students' learning of science (Gee, 2005; Lemke, 1990; Osborne & Freyberg, 1985; Sutton, 1996; Yore & Treagust, 2006), current instructional practices in science classes in Taiwan do not particularly encourage students to actively engage in the interchangeable use of L2 and L3 in discussing, debating, and reporting their ideas and findings. This is especially noticeable at the junior and senior secondary school levels, where teachers, students, and parents are very concerned about students' academic achievement. Although the curriculum guidelines emphasize scientific literacy – such as meaningful understanding of basic science concepts, a good understanding of the nature of science, and a scientific habit of mind, it is still the transmission of scientific knowledge that receives most attention at the junior and senior secondary school levels. Apparently, there is much more room for further research and educational efforts on the other parts of science literacy.

5. CONCLUSIONS AND SUGGESTIONS

An examination of the traditional Chinese cultural and language practices embedded in the use of Mandarin indicated that many Chinese idioms and proverbs tend to use metaphors, contrasts, and associations to make connections rather than basing on causal relationships. The habits of mind of traditional Chinese philosophers tend to be intuitive, metaphorical, descriptive, and holistic in contrast to the rational, causal, analytical, and reductive ways of thinking that are emphasized by western science.

In addition, there are distinctive features of Chinese words that may facilitate students' learning of science concepts. On the other hand, there are also cases where they tend to result in misconceptions, if the meanings of the words are interpreted or associated with other words superficially.

As mentioned earlier, there are a few recent studies that explored the effects of the distinctive features of Chinese words on students' learning of science. A search of literature yielded no relevant studies dealing with the potential impact of the contrasting traditional Chinese worldview and the scientific worldview on Taiwanese students' learning of science. Potential impacts of the traditional Chinese worldview on students' leaning of science appear to be an interesting research topic for future studies. In addition, since imagination, creativity, and concerns for natural environments are valued in the traditional Chinese worldview, it is perhaps a worthwhile instructional goal for students to understand the differences and similarities between the two worldviews. Various instructional strategies and techniques are available in the literature (Aikenhead, 2002), but they have to be adapted to Taiwanese contexts. Similar to what was emphasized by Yore and Treagust (2006), considerations in this direction appear to open a new door for the policymakers, science educators, and science education researchers in Taiwan.

The National Science Council (NSC) of Taiwan has funded several research and development projects to address indigenous students' learning, classroom practices, and instructional resources. As part of the works supported by the NSC, the author and other coworkers have recently produced a collection of indigenous artifacts to supplement school programs. These artifacts have been placed on public display at regional historical and technology museums to increase public awareness of aboriginal cultures, knowledge about nature, and ways of knowing before utilizing them as instructional resources. In addition, collaborative projects between and among indigenous scholars from Taiwan and the United States are in their preliminary stages.

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