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Science Education Curriculum Development Principles in Taiwan: Connecting with Aboriginal Learning and Culture

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ABSTRACT
This paper reflects thorough consideration of cultural perspectives in the establishment of science curriculum development principles in Taiwan. The authority explicitly states that education measures and activities of aboriginal peoples' ethnic group should be implemented consistently to incorporate their history, language, art, living customs, social system, ecology utilization, and value system. However, current educational practices in science education seriously neglect the importance of aboriginal cultures and values. To establish an index of curriculum development principles in Aboriginal Science Education, this study applies several research tools, such as fieldwork, expert interviews, panel discussions, and the Delphi method. Five dimensions are implemented to address the diverse needs of aboriginal students: local standard, cultural response, cognitive approach, learning interest, and learning effectiveness. The study aims to reach two specific perspectives: 1) promote Aboriginal Science Curriculum with valuable research findings to influence future policy making; and 2) assist aboriginal students in understanding the significance of culture aspects in their science education.
Keywords: aboriginal culture, curriculum development principles, delphi method, science education, culturally responsive teaching (CRT)

INTRODUCTION

In many countries around the world, science education curricula tend to adopt a solitary course or a unified structure of content to cover the diverse backgrounds of learners, neglecting the learners' cultural differences (Lee, 2001). Multicultural societies should reflect the actual demands of teaching and learning based on race, language, culture, status and position (Lin, 2008). Aikenhead (2002) suggested that to fulfil cross-cultural science education, aboriginal and Western science should use the same school curricula and methods of instruction. The students' mother culture establishes the learning model as the framework; therefore, the mother culture is not only a part of the curriculum, but she also provides a way of interpreting mainstream culture (Tan, Liu, & You, 2008).

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State of the literature

- Aboriginal cultural and aboriginal scientific conceptual knowledge have long been ignored and detached from the mainstream of science education curriculum.
- Relevant research focusing on Cultural Responsive teaching (CRT) sheds some light on blending aboriginal culture into science education curriculum. Based on CRT, students' cultural background, learning styles and their native ethnic characteristics are taken into consideration in curriculum design in order to provide fairer chances for students in learning.
- Aboriginal students are usually found to be less skillful in researching, planning, reasoning and organizing abstract concepts; however, they tend to apply diffusive thinking model in their reading.

Contribution of this paper to the literature

- This study urges the needs to construct scientific curriculum development with aboriginal culture elements to complement the current science curriculum development principles.
- This study applied five dimensions to reevaluate current science curriculum development: local standard, cultural response, cognitive approach, learning interest, and learning effectiveness and presented new science education curriculum development principles.
- Through science curriculum development principles which reflect aboriginal students' mother culture, students can enhance cultural understanding and appreciation and thus can have better opportunities to learn science from their cultural perspectives and to apply scientific knowledge in real life situations.

Due to findings mentioned above, to construct a profound structure that benefits students' learning as a whole, this study emphasizes the need to establish science curriculum development principles with aboriginal cultural implementation. As Gunn (2005) stated, in the process of globalization, the influence of individual cultural perspectives and historical backgrounds has varied and cannot be neglected in science education. Chen (2008) proposed that with the growth of multicultural education, contemporary scientific pedagogy tends to stress pluralism in science education so that students with diverse ethnic backgrounds can acquire educational liabilities and enhance their scientific and educational achievements. Science curriculum should also consider societal dimension, as suggested by German researchers (Marks, Stuckey, Belova, & Eilks, 2014), who aimed to encourage a more societal-scientific, issues-based science teaching. Fu (2004a) found that the content of the science curriculum significantly differs from the real life of aboriginal students. And because they are unable to make connections with the content, it might be difficult for these students to comprehend the context and inspire their learning intention. For example, current courses in the field of science and technology neglect the essentiality of students' overall life experience in aboriginal school districts, which results in a disparity between the content of courses and the students' perspectives of life (Xiong & Tsai, 2008). The underlying factors rely on restrained application of cultural diversities in science education, limited and unified science textbook content, and Han-orientated designed science education.

At present, there are only general guidelines for developing aboriginal curricula. There are not any detailed and systematic principles for designing aboriginal curricula. Therefore, this study aims to establish curriculum development principles for aboriginal science education. Firstly, this study establishes several dimensions of curriculum development principles by interviewing groups of experts, including teachers and principals in aboriginal schools, tribal elders, local cultural workers, and university professors who specialize in education. Subsequently, a panel discussion is held to examine the principles of curriculum development in detail. Finally, the curriculum development principle of aboriginal science education is presented using the Delphi method.

LITERATURE REVIEW

The Learning Features of Aboriginal Students

Science teachers have noted that the curriculum must include personal cognition, social culture, local spirit and scientific morals (Chinn, 2007). Gay (2000) proposed that "cultural differences" are the main obstacle to minority students adapting to current science curricula. He suggested that teaching should be rooted in a cultural context, with the curriculum designed to be composed of diverse ethnicities and cultures, linking the learning process to the students' mother culture. The learning features of aboriginal students are summarized as follows:

(1) Teaching Methods

Liu (1987) and Liu and Ji (1999) both noted that dynamic instruction leads to better learning results for aboriginal students. Dynamic instruction, such as game-based design, is most effective in teaching math and science. Tan and Lin (2002) discovered that when images and objects were used during the teaching process, Atayal students grew more interested. Research conducted among aboriginal students in Australia and Aotearoa, New Zealand has suggested that the most influential teaching strategies that may affect student autonomy in science are those that indigenous and non-indigenous students experience least often (Woods-McConney, Oliver, McConney, Maor, & Schibeci, 2013). In the same study, they reported that effective teaching methods for both indigenous and non-indigenous students are student investigations and hands-on activities, with the activity design focusing on applications or models and interactions with students. Lo and Chang (2011) noted that proper teaching methods for aboriginal students should include three key elements: initiative, adaptive and interactive. The initiative element refers to providing a knowledge construct that is student-centered; the adaptive element refers to providing opportunities for learners to organize and experience the real world; and the interactive element refers to creating an environment for students to interact with others. These results clearly suggested that indigenous students might be fond of interactive, game-based teaching, as well as the images and videos that may be seldom used in traditional classrooms.

(2) Learning styles

Walker, Dodd, and Bigelow (1989) used the "Walker Learning Preference Scale" as a research tool and found that indigenous students prefer classroom discussions without a competitive atmosphere. Browne (1990) suggested that aboriginal children retained knowledge through the use of pictures and impressions that are not expressive, and through imitation of their teachers. Their learning style consists of enjoying cooperation and avoiding competition. Irvine and York (1995) found that indigenous students tend to have a "field dependency" learning style, such that they prefer to receive the information with vision, space and sense, which are non-verbal categories. It can be noted that they prefer to be given a full presentation of the learning materials, to study in private spaces rather than public locations, and to memorize using "mental images," instead of associating relationships between contexts. As Chen (2001) noted, regarding the primary school course unit about the orientation of north, south, east and west, some teachers in the mountainous area expressed that aboriginal children have certain difficulties with the lesson. Aboriginal students judge orientation based on landforms and ground surfaces, using phrases such as "over the field," "behind the mountain," and "next to the river." Concepts of orientation are not practical and meaningless, reflecting the difficulties aboriginal students may face in reading text materials in school.

(3) Thinking models

Li (1998) found that most indigenous students are diffusive and adaptive thinkers; they are not keen planners and do not use thinking models. She stated that they are not good at forming conceptual ideas or logical reasoning, and they lack research and planning skills. If teachers can understand the preferred overall, inductive and direct thinking models of indigenous students, they will be able to design suitable curricula (Chen, 2008). On-site research indicated that indigenous students may need more assistance when facing learning obstacles because they usually encounter difficulties when forming questions and requesting more instructions from teachers (Tai & Leou, 2006). In its conclusion, this study proposes curriculum development principles that focus on aboriginal students' learning features, create expectations for teachers to design science courses by those principles, increase the students' learning motivation, and enhance their learning accomplishments.

Cultural Responsive Teaching

Cultural responsive teaching (CRT) emphasizes the ways in which teachers should recognize the cultural implications of their students' behavior, and thereby avoid judging students' learning behavior based on mainstream culture (Lin, 2008). Students should not be treated as homogenous, and teachers should implement adaptive instructions according to the students' cultural differences (Liu, 2001). CRT is the core design of the curriculum development principle in this study. It emphasizes that the mother culture is not only a part of the curriculum, but it is also a tool to connect and interpret mainstream culture.

This study targets a class of fourth graders within a certain indigenous tribe in Nanao Township, Yilan County. To begin, the teacher used a film to introduce the ways that transportation became extremely convenient after the high speed rail was built in western Taiwan, reducing travel time between northern and southern Taiwan. The students showed different reactions: some tried very hard to imagine the new transportation tool described by the teacher, but most were confused and felt strange about what the teacher was explaining. Because these indigenous children rarely have the opportunity to travel outside of their tribe's region, the concept of the "high speed rail" invokes a distant and incomprehensible world for them (Liu, 2010). This example illustrates that the curriculum content is seriously disconnected from the experience of the minority students, who barely grasp the meaning of the lessons.

Gay (2000) proposed CRT, which entails curriculum and instruction that is based on the features of student tribes, considering students' cultural background and learning styles, using their mother culture as a bridge, and helping students from different cultural backgrounds to have an equal chance at performing well. Such a teaching style is highly important for students in aboriginal tribes. There are six characteristics of CRT (Gay, 2000), which are described below:

(1) Validating: CRT affirms students' cultural knowledge, prior experience, association and learning style. With these factors, learning becomes more meaningful and more effective.
(2) Comprehensive: Teachers should use culture to guide intellectual, social, emotional and political development to guide cognitive, affective and skillful learning.
(3) Multidimensional: Multidimensional responsive teaching emphasizes the course contents, learning context, classroom atmosphere, teacher-student relationships, teaching skills and assessments.
(4) Empowering: CRT is student-centered. Students are the targets of teaching; they are also the producers of knowledge, with the goal of empowering them and helping them become successful learners.
(5) Transformative: CRT challenges the traditional educational habit that encourages a more respectful teaching approach for minority students. The teaching strategy is transformed according to the students' learning characteristics, and academic achievement and cultural consciousness are discovered simultaneously. It will increase students' capabilities and allow them to succeed in schoolwork.
(6) Emancipatory: CRT teaching is meant to emancipate by releasing students from regulations and cognitions of mainstream knowledge, as well as by providing the opportunities for students to learn about different ethnic cultures.

According to the above literature review, the study of the curriculum development principle is divided into five dimensions, which will be further analyzed: local-based, cultural responsive, cognitive style, learning interest, and learning effect.

Aboriginal science and Western science

Due to the impact of globalization, aboriginal knowledge of different tribes has been assimilated, or it has gradually disappeared. When exploring aboriginal culture, many scholars and experts argue that young aboriginal groups devalue their own culture and show no interest in it. For these young aboriginal groups, Western scientific knowledge is much more important than their mother culture (Quigley, 2009). As a matter of fact, the world in which indigenous people live involves extremely long contact and experiences with nature, from which they gain traditional ecological knowledge (TEK) (Snively & Corsiglia, 2001). As a result of cultural differences, each ethnic group develops a different TEK, meaning a science exists within every culture, yet it is expressed and presented differently (Cobern & Loving, 2000). The scientific knowledge of Yi-Lan tribe indigenes is as follows: Elderly ancestors of the Atayal tribe marinated bitter flower fish with salt and cooling rice (the Atayal referred to this as *kole-balai*, meaning "real fish;" and it was also referred to as "elder fish" because only elders were allowed to eat it due to its preciousness). They piled up and layered the cooling rice and salted bitter flower fish. The rice produced acetic acid after a series of natural fermentation process, and it slightly acidified the bitter flower fish to achieve a better anti-corrosion effect. This prevented the bitter flower fish from becoming rotten. The scientific concept in the process contains osmotic pressure and a fermentation reaction, and the biological and ecological concepts in the process focus on the bitter flower fish (Fu, 2004b).

Wang, Xie, Li, Yang, Yang, and Liao (2006) found that Amis tree leather is made of durable plant fibres, and the main material is tree bark. The Amis of an electro-optic tribe in Taitung used the puncture bamboo to make bamboo firecrackers. They placed calcium carbide with water to form acetylene in bamboo, and then ignited it to produce an explosive sound to drive birds and animals away. Another example comes from the members of the Paiwan and Rukai tribes, who, whether male or female, may worry about their tattoo wounds becoming irritated or infected. They usually have their tattoos made during the winter because the weather is cooler. If a tattoo is made during hotter seasons, wounds are more easily infected. Once the tattoo is completed, they disinfect the wound, and thus avoid inflammation, by putting ashes on the wound's surface (Chen, 2008).

Scientific knowledge of indigenous people and Europeans alike has been accumulated from long years of experience, but indigenous people focus more on the profound understanding an individual has of such knowledge. Aikenhead (2006) noted that to achieve cross-cultural science teaching, aboriginal and Western science should be integrated into the curriculum and instruction, applying rational ways of pursuing knowledge. The differences between the two approaches rely on social objectives, intellectual goals, related human actions, effectiveness, and other aspects. However, aboriginal scientific knowledge cannot be interpreted fully by Western scientific systems, so we should pay more attention to multi-cultural science education. Hence, the design of indigenous science curricula should fully utilize the knowledge of nature that has been passed down by ancestors, to help indigenous students cross over the cultural barrier between indigenous and Western science. This will

allow science education in schools to be combined with the living experiences of indigenous students and further produce meaning (Aikenhead, 2006).

METHOD

Using a literature review, fieldwork, expert interviews, a panel discussion and the Delphi method, a set of curriculum development principles that are based on aboriginal culture was developed. First, related multicultural and indigenous literature in science education was collected. Then, the basic framework of the curriculum development principles was drafted. We followed the basic framework for in-depth tribal fieldwork and interviewed four teachers who are teaching in aboriginal schools, four tribal elders, and one local cultural worker, obtaining first-hand information to overcome the inadequacy of secondary data from literature reviews. After reviewing the literature and surveying the fieldwork, a group of specialists in multicultural and science education was interviewed to determine whether the obtained information would make essential points about the curriculum development principles, and to find its true spirit. The next step was to form a panel discussion, with the aim of confirming the dimensions and structure before initiating the curriculum development principles. The final step was to apply the Delphi method to confirm curriculum development principles, conduct the Delphi questionnaires twice, and finally reach agreements with the experts.

The fieldwork, expert interviews, panel discussion and Delphi method are described below:

(1) Fieldwork

This study obtained first-hand information through "direct observation." We conducted field surveys and interviews, and collected records and films from local areas and neighboring environments in the tribe. Indigenous habits in daily life, traditional customs, and tribal stories from their oral descriptions were observed and used as a basis for establishing curriculum development principles.

The study involved visiting the tribes six times, interviewing four tribal teachers, four tribal elders and a local archivist. The respondents in the fieldwork were predominantly female because most of the men in the tribes worked elsewhere, and the teachers and tribal elders we interviewed were mostly female. The background information is shown in **Table 1**. Tribal teachers worry that aboriginal tribes are severely influenced by Han culture and that the traditional indigenous culture is gradually declining (Tribal teacher B, C, D, 20091021).

Aboriginal elders explained that aboriginal customs and spirits, which can be memorized through conversations and singing between the elders, no longer exist. Currently, children must be stimulated by new knowledge to gain competitiveness (Tribal elders A, B, 20091209). Local archivists, however, strongly advocate preserving indigenous culture. They

Table 1. The respondents' fieldwork data

Respondents	Gender	Remark
Tribal teacher A	Male	Principal at an aboriginal elementary school
Tribal teacher B	Male	Director of the Academic Affairs Office, Aborigine
Tribal teacher C	Female	Sixth grade science and technology teacher at an aboriginal elementary school who got married and stayed in the tribe.
Tribal teacher D	Female	Fourth grade science and technology teacher at an aboriginal elementary school.
Tribal elder A	Female	Owner of a grocery store who experienced being kidnapped and married.
Tribal elder B	Female	Former employee at a Hotel in Taipei for 35 years who returned to the tribe after retirement. Had the experience of eating raw monkey brains.
Tribal elder C	Female	Learned to hunt and set up traps to catch wild boar at a young age.
Tribal elder D	Female	Held a grudge for being forbidden to use aboriginal languages during the Japanese Colonial Period. Very good at brewing millet wine.
Local cultural worker	Male	Returned to the tribe after a discharge from the army.

use videos, books, and oral dictation to write down traditions and customs that have nearly been abandoned (Local cultural worker, 20091215).

(2) Expert interviews

Four experts in multicultural education and science education were interviewed, examining the data from the literature reviews and fieldwork, determining the main features of the aboriginal learning style, and ensuring that the curriculum development principles would include aboriginal local culture. The experts described their own experiences and opinions and wrote detailed notes. The respondents' suggestions were organized with explicit information, encouraging an in-depth introduction and analysis so that aboriginal curriculum development principles would be closer to the demand to reach substantial benefits.

Multicultural education experts sought to clarify how the science curriculum will be based on curriculum development principles. Can it incorporate an aboriginal cultural context while letting aboriginal children maintain their own culture? Or would the aboriginal children participate in social activities or internships after taking these courses? (Respondent B, 20091118) The experts also mentioned that the key point of curriculum development is to increase aboriginal students' cultural awareness and to promote cultural awareness of tribes. The curriculum design should allow students to experience, reflect on and apply concepts (Respondent C, 20091119). Furthermore, they specifically mentioned the importance of "learning by doing" for aboriginal students; they believe that aboriginal students prefer active learning and that their interest is higher during the physical classroom activities (Respondent C, 20091202).

The data on the experts' backgrounds are shown in **Table 2**.

Table 2. Background information on the experts

Experts	Gender	Remark
Respondent A	Female	Professor at National Taipei University of Education, Expert in Aboriginal Culture
Respondent B	Female	Professor at National Taiwan Normal University, Expert in Multicultural Education
Respondent C	Female	Professor at National Taipei University of Education, Expert in Multicultural Education
Respondent D	Female	Professor at National Taipei University of Education, Expert in Science Education

(3) Panel Discussion

After completing the interviews, a basic prototype has been developed for aboriginal curriculum development principles in science education. To avoid bias during the expert interviews, the study conducted another panel discussion, which focused on the mode of aboriginal curriculum development principles and discussions with scholars and professionals in the related field. The discussion also involved exchanging academic and practical opinions, discovering the differences, and revising the controversial parts of aboriginal curriculum development principles.

The panel discussion was attended by nine professionals, and the data of the professionals are shown in **Table 3**.

One of the experts from the Commissioner of the Council of Indigenous People, Executive Yuan, paid particular attention to indigenous languages. He mentioned that the commonly used tribal terms in the textbooks should be incorporated into local indigenous languages so that students would understand the meaning, and the tribal languages will continue to be passed along (Professional F, 20100121). Additionally, an aboriginal teacher noted important considerations for the types of exam questions. If they were text-based, students would find them hard to understand. To help the aboriginal students understand them, the exam questions needed to be mostly illustrated in diagrams (Professional H, 20100121). The experts generally concluded that the core design of science course content should connect with scientific perspectives in aboriginal daily life.

The tribes occasionally held some traditional athletic competitions, such as sawmill games, archery and tug of war competitions, which not only allowed children to be involved in competitive games but also helped them understand similar principles that were cited in their lessons (Professional E, 20100121). The expert who specialized in instruction design suggested the need to increase the proportion of aboriginal culture in the teaching materials. She believed that aboriginal culture was the minority among a majority of the more prominent Han culture, and the current curriculum was mostly centered on the Han. Under the examination system, the ratio of Han culture and aboriginal culture is 7 to 3, which must be modified and addressed in curriculum design (Professional D, 20100121).

Table 3. The data for the professionals in the panel discussion

Respondents	Gender	Remark
Professional A	Male	Professor at National Taipei University of Education, Expert in IT Education
Professional B	Male	Professor at National Taiwan Normal University, Expert in Science Education
Professional C	Male	Professor at a Private University, Expert in Science Education
Professional D	Female	Professor at National Taipei University of Education, Expert in Instruction Design
Professional E	Female	Professor at National Taiwan Normal University, Expert in Multicultural Education
Professional F	Male	Commissioner of Council of indigenous people, executive Yuan, Expert in Aboriginal Education
Professional G	Male	Principal at an Aboriginal elementary school
Professional H	Male	Director of Academic Affairs office at an Aboriginal elementary school
Professional I	Female	Teacher of Science and Technology at an Aboriginal Elementary School

Table 4. The data from the Delphi Method

Delphi Experts	Gender	Remark
Delphi Expert A	Male	Professor at National University, Expert I Multicultural Education
Delphi Expert B	Female	Professor at National Taiwan Normal University, Expert in Science and Math Education
Delphi Expert C	Male	Professor at National Taiwan Normal University, Expert in Science Education.
Delphi Expert D	Male	Commissioner of Council of indigenous people, executive Yuan, Expert in Aboriginal Education
Delphi Expert E	Female	Professor in National Taipei University of Education, Expert in Aboriginal Education
Delphi Expert F	Male	Principal at an Aboriginal elementary school
Delphi Expert G	Female	Professor at National Taipei University of Education, Expert in Science Education
Delphi Expert H	Female	Professor at National Taiwan Normal University, Expert in Science and Multicultural Education
Delphi Expert I	Male	Professor at National University, Expert in Curriculum and Instruction
Delphi Expert J	Male	Director of Academic Affairs Office at an Aboriginal elementary school

(4) Delphi Method

This study uses literature review, fieldwork and expert interviews to establish 5 dimensions of curriculum development principles. A panel discussion was then held to determine curriculum development principles in each dimension, and the curriculum development principles were verified using the Delphi method twice. The Delphi method is an interdisciplinary research method that integrates specific issues, such as professional knowledge, experience, and opinions from the experts in the related field to approach an agreement, and accordingly enhance the quality of decision-making to solve complex issues (Webb, 1996). It relies on the expertise and value judgments of the participants, including experts and professionals. The study of aboriginal curriculum development principles is generally established through expert interviews and a panel discussion. Afterwards, the aboriginal curriculum development principles are listed, and using the Delphi method,

Table 5. Modified curriculum development principles after the first Delphi method

Curriculum development principles of the first Delphi method	Modified curriculum development principles
A-4 Curriculum design should coordinate with local tribes, starting from the surrounding environment.	A-4 Curriculum design should consider the cultural context of school districts, edited to suitable teaching materials for local schools.
B-3 Courses design should allow non-aboriginal students to reduce the impression of certain stereotypes of aboriginal culture.	B-3 Curriculum design allows non-aboriginal students to realize, accept and respect Aboriginal culture.
B-4 Course content should be based on local Aboriginal culture.	B-4 Course content should increase the proportion of local Aboriginal culture.
C-4 Course design should range from easy to difficult in considering Aboriginal students' understanding.	C-4 Curriculum design should range from easy to difficult in the explanation of words so that Aboriginal students can understand the content.
C-7 Examinations should mainly consist of simulated tests, and they should contain diagrammatic questions.	C-7 Examinations should be based on simulated tests, and they should mainly consist of diagrammatic questions.
C-8 Curriculum design should consider the students' own area of expertise as the basis of an integrated curriculum.	C-8 Curriculum design should consider the students' own area of expertise as the basis of an integrated curriculum (For example: Art and Humanities)
D-1 Curriculum design should adopt more visual images	D-1 Curriculum design should adopt multisensory materials to achieve the communication purpose.

questionnaires are emailed to ten experts in the related field in Taiwan. The data of the Delphi experts are shown in **Table 4**.

RESULTS

Using the Delphi method, the study reached agreements by using two questionnaires. After the statistics of the first Delphi method survey corrected for the development principles of average numbers smaller than four and standard deviations greater than one, seven development principles emerged. Curriculum development principles of the first Delphi method and the corrected curriculum principles are shown in **Table 5**. Using the Delphi method, the second questionnaire survey was revised and conducted based on the experts' opinions. The statistic results showed that all average numbers of principles are greater than four and standard deviations are smaller than one, confirming the curriculum development principles in this study.

Throughout the process of completing expert interviews, a panel discussion, and two applications of the Delphi method questionnaires, the study confirmed that each principle in the scope of "Curriculum development principles in Aboriginal Science Education" has reached average numbers greater than four, and the standard deviation is smaller than one. The five dimensions are (1) local standard, (2) cultural response, (3) cognitive approach, (4) learning interest, and (5) learning effectiveness. The thirty principles of development policies are shown in **Table 6**.

Table 6. Curriculum development principles in Aboriginal science education

Development principles	Mode	Mean	Standard deviation
A Local Standard			
A-1. Curriculum design should bring tribal history and culture into the course content, introducing the process of formed and accumulated local culture (such as trap theory, rattan as the central axis principle, etc.) as the initiation of knowledge in local standards.	5	4.90	.316
A-2. Curriculum design should start from the experiences of daily life, combining local traditional festivals, and introducing new scientific concepts.	5	5.00	.000
A-3. Curriculum design should coordinate with local tribes so that students renew the features of local culture from the surrounding environment.	4	4.50	.527
A-4. Curriculum design should consider the cultural context of school districts and edit them into suitable teaching materials for local schools.	5	4.90	.316
A-5. Curriculum design should embed the elements of diverse culture and increase cultural experience outside the local culture.	5	5.00	.000
B Cultural Response			
B-1. Curriculum design should pay attention to the integration of Western science and to the features of Aboriginal culture	4	4.40	.516
B-2. Curriculum design should emphasize the subjectivity of Aboriginal culture and respect the interpretation of the culture of local tribes.	5	4.90	.316
B-3. Curriculum design should allow non-aboriginal students to realize, accept and respect Aboriginal culture.	5	4.80	.422
B-4. Course content should increase the content of local Aboriginal culture.	5	4.40	.699
B-5. Curriculum design should take into consideration the students' differences and similarities.	5	4.90	.316
B-6. Curriculum design should emphasize the relevance of interdisciplinary studies and culture.	5	4.90	.316
B-7. Curriculum design should enable students to recognize their own tribal culture, while appreciating and valuing other tribal cultures.	5	5.00	.000
B-8. Curriculum design should consider things from different angles and tolerate different opinions.	5	4.90	.316

(1) Local Standard

The local standard consists of five aspects of curriculum developmental principles. A professor at the National Taipei University of Education proposed that, among these policies, the curriculum design should embed more ethnic history and aboriginal culture into the related subjects, and introduce more details about the process of formed and accumulated local culture, which produces the humanities and the arts (Expert D, 20100121). The Director of Academic Affairs at an aboriginal elementary school participated in the panel discussion, mentioning that curriculum design should incorporate more local affairs (such as trap theory and rattan as the central axis principle) for the initiation of student knowledge in the local standard (Expert H, 20100121). This approach corresponds with the development principle A-1 (**Table 6**), which indicates that curriculum design should bring tribal history and culture into the course content, introducing the process of formed and cumulated local culture (such as

trap theory and rattan as the central axis principle) for the initiation of knowledge in the local standard.

The expert in multicultural education believes that courses must combine aspects of aboriginal daily life. Tribes occasionally hold traditional athletic competitions, such as sawmill games, archery and tug of war competitions, necessarily involving children in those games and assisting them to explore similar principles that are cited in the course contents (Professional E, 20100121). This approach corresponds with the development principle A-3 (**Table 6**), which indicates that curriculum design should coordinate with local tribes, and students should reacquaint themselves with the features of local culture from their surrounding environment, which also reflect on the native culture of aboriginal students.

The aboriginal science and technology teacher at the aboriginal elementary school mentioned that courses about tribal plants and animals should be combined with topics about the local national environment so that students would further understand the local flora, fauna, and features (Tribal teacher C, 20091021). This approach corresponds with the development principle A-4 (**Table 6**), which indicates that curriculum design should consider the cultural context of school districts and edit suitable teaching materials for local schools. This dimension of curriculum development principles is consistent with Fu (1999), who proposed that students need guidance from teachers' instructions and teaching materials to bridge the gap between science and daily life experiences, to gain experience in the field of science and also meaningful scientific learning.

(2) Cultural Response

Cultural response consists of eight aspects of curriculum development principles. Among these policies, the Commissioner of Council of indigenous people mentioned in the panel discussion that the course content should allow aboriginal children to "cherish their own ethnic culture" and "recognize their own tribal cultures" (Professional F, 20100121). This corresponds to the development principle B-2 (**Table 6**), which indicates that curriculum design should emphasize the subjectivity of Aboriginal culture and respect the interpretation of the local tribes' culture.

The expert who specialized in Instruction Design proposed that aboriginal culture is the minority among a majority of the stronger Han culture, and the current curriculum is centered primarily on the Han. In the panel discussion, he reported that the exams mainly address the Han living experience, unless there is extra teaching time when teachers would be able to teach indigenous culture. Moreover, under the examination system, the ratio of Han culture and aboriginal culture is 7 to 3, which must be modified and paid attention to in curriculum design (Professional D, 20100121). This corresponds to the development principle B-4 (**Table 6**), which indicates that course content should increase the proportion of lessons related to local Aboriginal culture.

In addition, the professor in multicultural education of National Taiwan University of Education mentioned that curriculum design should cover the introduction of other ethnicities so that the students will understand, appreciate and respect other ethnic cultures (Respondent B, 20091118). This approach corresponds with the development principle B-7 (**Table 6**), which indicates that curriculum design should enable students to recognize their own tribal culture, while appreciating and valuing other tribal cultures. This dimension of the curriculum development principle is consistent with the opinion of Banks (2006), who indicated that school education not only informed students' knowledge, attitude and skills toward to their own social groups but also combined cultural elements of other regions into curriculum and textbooks, helping the individuals gain multicultural knowledge.

(3) Cognitive Approach

The cognitive approach consists of eight aspects of curriculum development principles. During the fieldwork, the principal of an aboriginal elementary school proposed that aboriginal children are usually much more engaged when given the opportunity to manipulate items. They lose concentration easily during the teacher's lecture and are only motivated when given the opportunity to learn with hands-on activities (Tribal teacher A, 20091119). The expert in instruction design mentioned that aboriginal children can concentrate well and are extremely sensitive to their feelings during the process of operating, touching, and feeling. She particularly noted that students' curiosity and thirst for knowledge comes from observing minor changes (Professional D, 20100121). This approach corresponds with the development principle C-1 (**Table 6**), which indicates that curriculum design should meet the principle of "learning by doing" and gaining experience by performing actual drills.

The teacher of aboriginal science and technology suggested that aboriginal children enjoy learning in small groups and informal, harmonious learning environments, and they do not prefer the competitive learning style (Tribal teacher C, 20091021). This is very different from the Han students, who prefer a competitive learning style.

During the panel discussion, the Director of Academic Affairs at an aboriginal elementary school proposed that aboriginal children prefer studying in groups, acting together, and doing homework together, whether they are at school or working after school. When they have problems with tasks, they prefer to ask their peers for help (Professional H, 20100121). This is extremely different from the Han students, who ask their parents questions or approach their school teachers for help. This approach corresponds with the development principle C-2, which indicates that curriculum design should emphasize group activities and encourage students to participate in group discussions.

The principal of the aboriginal elementary school mentioned in the fieldwork that aboriginal children are weak with regards to logical analysis, and the course content should range from easy to difficult to guide them with their learning (Tribal teacher A, 20091119). The commissioner of the Council of indigenous people mentioned that the commonly used tribal terms in the textbooks should incorporate local indigenous languages so that students could

Table 6. Curriculum development principles in Aboriginal science education (continued)

Development principles	Mode	Mean	Standard deviation
C Cognitive Approach			
C-1. Curriculum design should adhere to the principle of "learning by doing" and experiencing by actual drills.	5	4.90	.316
C-2. Curriculum design should emphasize group activities and encourage students to participate in group discussions.	5	4.40	.699
C-3. Curriculum design should maintain aboriginal subjectivity.	5	4.80	.422
C-4. Curriculum design should range from easy to difficult in the explanation of words so that Aboriginal students can understand the content.	5	4.40	.699
C-5. Curriculum design should encourage students to observe real objects	5	4.70	.483
C-6. Curriculum design should build up mutual interaction between teacher and students to create rich and diverse learning environment.	5	4.60	.516
C-7. Examinations should be based on simulated tests, which consist mainly of diagrammatic questions.	5	4.10	.876
C-8. Curriculum design should consider the students' own area of expertise as the basis of an integrated curriculum (For example: Art and Humanities)	5	4.50	.850
D Learning Interest			
D-1. Curriculum design should adopt multisensory materials to achieve the communication purpose.	4	4.20	.422
D-2. Curriculum design should include learning activities such as games.	4	4.20	.630
D-3. Curriculum design should include outdoor activities to allow students to learn by exploring	4	4.30	.483
D-4. Curriculum design should integrate multimedia and new technology.	4	4.20	.632
E Learning Effectiveness			
E-1. Curriculum design should enhance aboriginal students' confidence and self-value.	5	4.50	.707
E-2. Curriculum design should improve aboriginal students' learning effectiveness.	5	4.60	.699
E-3. Curriculum design should enrich aboriginal students' creativity.	5	4.60	.699
E-4. Curriculum design should increase aboriginal students' cognitive ability.	5	4.30	.823
E-5. Curriculum design should expand aboriginal students' vision and worldview.	5	4.50	.850

understand the meaning, and the tribal languages will continue to be passed along. (Professional F, 20100121). This approach corresponds to the development principle C-4, which indicates that curriculum design should comply with the principles that vocabulary words should range from easy to difficult so that aboriginal students can understand them.

During the fieldwork, the Director of Academic Affairs at an aboriginal school explained that exam questions are text-based, and students generally find them difficult to understand. The students need diagrams to help them understand the questions (Tribal teacher B, 20091021). This approach corresponds with the development principle C-7 (**Table 6**), which indicates that examinations should be based on simulated tests that consist mainly of diagrammatic questions.

The expert in curriculum and instruction suggested in the first questionnaire of the Delphi method that if teachers integrated aboriginal students' favorite sports, songs, dances,

textbook pictures, and other actual examples from daily life into the teaching materials, the aboriginal students would often enthusiastically participate in the discussions (Delphi Expert I, 20100316). This approach corresponds with the development principle C-8 (**Table 6**), which indicates that curriculum design should consider the students' own areas of expertise as the basis for an integrated curriculum (i.e., Arts and Humanities). This dimension of curriculum development principles is consistent with Chao (2013), who believes that collaborative learning not only increases motivation in indigenous students and makes them learn more enthusiastically but also improves their creativity and problem solving abilities. Additionally, Li (1998) argued that indigenous students perform better when answering illustrated questions on a test.

(4) Learning Interest

In this section, learning interest consists of four aspects of curriculum developmental principles. Among these policies, the Director of Academic Affairs at an aboriginal school proposed in the fieldwork that teachers select textbooks that come with multimedia materials because students prefer course contents presented with multimedia over lectures (Tribal teacher B, 20091021). This approach corresponds with the developmental principle D-1 (**Table 6**), which indicates that curriculum design should adopt multisensory materials to effectively communicate with the students.

As reported from the fieldwork, the aboriginal teacher mentioned that, by allowing their students to experience the learning directly, some instructors lead students to the playground to identify wild animals or plants from their surroundings (Tribal teacher D, 20091021). This approach corresponds to the development principle D-3 (**Table 6**), which indicates that curriculum design should include outdoor activities to allow students to learn by exploring. The teacher also noted that aboriginal children enjoy playing computer games, and they can pay better attention while playing on digital media. If some course units were to contain computer games, this would increase the students' interest (Tribal teacher D, 20091021). This approach corresponds with the developmental principle D-4 (**Table 6**), which indicates that curriculum design should integrate multimedia and new technology. This dimension of curriculum development principles is consistent with Liu (1987) and Liu and Ji (1999), who noted that dynamic instruction leads to better learning effects on indigenous students. Dynamic instruction is most effective in teaching math and science using games.

(5) Learning Effectiveness

Learning effectiveness consists of five aspects of the curriculum development principles. Among these policies, the Director of Academic Affairs at an aboriginal school proposed that aboriginal children do not have enough self-confidence. They care about scores, but they do not have faith in the tests and avoid the examinations as much as possible, which makes them different from Han students, who are self-confident. Thus, curriculum design should enhance the self-confidence of aboriginal children (Tribal teacher B, 20091021). This approach

corresponds with the development principle E-1 (**Table 6**), which indicates that curriculum design should enhance the aboriginal students' confidence and self-value.

The respondent also mentioned that general courses are restrained, perpetuating the stereotype that aboriginal students do not possess their own sense of imagination and creativity. The courses should include some activities that are related to the contents that inspire the students' imagination (Tribal teacher B, 20091021). This approach corresponds with the developmental principle E-3 (**Table 6**), which indicates that curriculum design should enrich the aboriginal students' creativity.

The expert in multicultural education at the National Taiwan Normal University suggested that aboriginal students lack inspiration and stimulation with regard to knowledge in the fields of culture, technology, and history. Therefore, the curriculum design should encourage and allow students to learn about other regions and countries (Expert B, 20091118). This approach corresponds with the developmental principle E-5 (**Table 6**), which indicates that curriculum design should expand the aboriginal students' vision and worldview. This dimension of curriculum development principles is consistent with Tan and Lin (2002), who believed that indigenous students generally have insufficient self-confidence and that curriculum design should be able to improve their self-confidence and sense of achievement, as well as Wu and Huang (2009), who proposed that indigenous curriculum design should correspond with principles of cultivating citizens with an international perspective.

CONCLUSION

This study presented a systematic overview of curriculum development principles in Aboriginal Science Education. The course value was revealed and clearly addressed the importance of individual ethnic backgrounds that cannot be neglected in science learning. And to achieve better learning effectiveness, features of aboriginal culture should be integrated and implemented in science curriculum. Therefore, the curriculum development principles in the study include five dimensions: (1) local standard, (2) cultural response, (3) cognitive approach, (4) learning interest, and (5) learning effectiveness. Thirty principles of development policies address the aboriginal students' teaching method, learning style, thinking model, and local culture through literature reviews, fieldwork, expert interviews, panel discussions and the Delphi method. Local standard emphasized that curriculum design should combine daily life and strengthen the values of the local standard. Following that, the second dimension of cultural response proposed that curriculum design should respect the subjectivity of each ethnic group, tolerate other cultural groups, and admire and understand different cultures. Cognitive approach, the third dimension, focused on the principles that curriculum design should be practical by letting students manipulate with their hands. Then, the dimension of learning interest suggested that curriculum design should utilize multimedia and allow students to go outdoors. The final dimension, learning effectiveness, importantly emphasized the ways in which curriculum design should enhance the students' confidence and cultivate their overall worldview. Teachers can use "Local Standard" and "Cultural Response" as the

basis for designing curricula, and use "Cognitive Approach," "Learning Interest" and "Learning Effectiveness" as the basis for teaching design and teaching strategies. By making the effort to establish principles for better science courses, researchers hope that an improved curriculum will provide aboriginal students with an understanding of their own culture, as well as an understanding of the features and spirit of different cultures, by perceiving cultures differently, studying and absorbing the notion of science, and providing practical suggestions for scientific concepts.

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