

Case Report

Integrating Science, Technology, Engineering, and Mathematics (STEM) into Indigenous Education for Sustainability: The Development and Implementation of a Curriculum Based on Disaster Prevention for Young Children

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Abstract: There are differences between Western mainstream culture and traditional Indigenous culture in the way they address sustainable development. The spirit of sustainability has been emphasized and practiced by Indigenous cultures for hundreds or even thousands of years, but it is increasingly disappearing over time due to the threat of natural disasters. It is necessary to recover this practice of sustainable development from its roots in traditional Indigenous knowledge. This study considers the possibility and utility of incorporating science, technology, engineering, and mathematics (STEM) into Indigenous education for sustainability, a topic that has not been addressed by other studies. Based on a literature review, the proposed framework and content for this study focus on Indigenous disaster prevention. The specific topic was chosen to be most relevant to young Indigenous children. STEM indicators from the US next-generation science standards (NGSS) were referenced to create the proposed STEM teaching objectives, which were designed to be specifically appropriate for Indigenous curricula and teaching activities. Additionally, the cultural curriculum model was adopted to reform the Indigenous curriculum and teaching model by utilizing the transformation and social action approaches. Finally, the five-stage learning cycle was used as the framework to implement the curriculum, intertwined with the principles of the spiral curriculum, to co-construct an instructional example of Indigenous education for sustainability for future reference.

Keywords: disaster prevention; development for sustainability; education for sustainability; Indigenous young children; STEM



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1. Background and Problem Awareness

The survival of Indigenous cultures on the Earth for millennia is due to their traditional emphasis on the sustainable co-development of humans and the environment [1,2]. However, in recent decades, human activities have altered global climate patterns, leading to increasingly severe and frequent extreme weather events that threaten the survival and cultural continuity of Indigenous peoples [3]. Taiwan's land area is exposed to more than three kinds of natural hazards, and in 2005, 73% of the population were threatened by these disasters, ranking the highest in the world [4]. In recent years, several severe typhoons have devastated the living environments of Indigenous communities in Taiwan. For instance, Typhoon Morakot caused unprecedented rainfall, heavily damaging the southern regions of the country, resulting in nearly 700 deaths and disappearances, and NTD 28 billion in property losses [5]. Statistics show that Indigenous people comprised over 70% of the total population forced to relocate due to the typhoon disaster [6]. Among these Indigenous groups, the Rukai people in Pingtung suffered the most severe damage. All residents in three out of eight Rukai villages in Wutai Township were relocated to lowland areas,

considerably impacting them materially, spiritually, and culturally in terms of post-disaster trauma, cultural and historical memory transmission, and Rukai cultural identity [7]. This indicates that sustainability-focused Indigenous cultures are facing survival threats caused by economic activities originating from the majority culture and extreme weather events. The sustainable inheritance of Rukai culture is particularly endangered, so promoting its sustainable development is vital.

Taiwan has recognized the importance of disaster preparedness education for sustainable development and has been funding the establishment of disaster-resilient schools since 2011 and promoting the “School Disaster Risk Reduction and Climate Change Adaptation Improvement Plan”. The 2015 United Nations 2030 Agenda for Sustainable Development included 17 sustainable development goals (SDGs), such as ending hunger, quality education, reducing inequalities, sustainable cities and communities, climate action, life on land, peace, justice, and strong institutions [8]. This global push for sustainable development has kept disaster preparedness education a focus in Taiwan. However, despite two decades of disaster education initiatives, only 1603 out of 10,928 schools nationwide have established disaster-resilient campuses, accounting for 15% in 2020. Among these, only 31 disaster-resilient kindergartens (0.5% of the 6447 kindergartens existing in 2020) have been established, and the majority are in non-Indigenous areas [9]. Not a single Rukai kindergarten has participated in or been included in this disaster plan [10], indicating a significant lack of attention to early childhood disaster education, particularly among Rukai children, who face considerable disaster threats.

Furthermore, Taiwan’s disaster education for sustainable development seems to emphasize passive prevention and disaster response, neglecting the revitalization of traditional Indigenous culture and knowledge. Effective disaster education should focus on proactive measures that support the survival of Indigenous groups and environmental sustainability. For instance, teaching Rukai children how to plant millet and sweet potatoes and store them long term can help develop their environmental awareness and disaster preparedness behaviors, achieving long-term SDGs [11,12]. Currently, however, teachers in Rukai kindergartens are mainly non-Indigenous, often prioritizing non-Indigenous content and providing limited exposure to the community’s historical artifacts, failing to emphasize the significance of traditional knowledge for disaster prevention and mitigation. Consequently, Rukai disaster education is crucial for the preservation and transmission of their traditional culture and knowledge.

Scholars argue that traditional Indigenous knowledge can improve modern scientific knowledge and vice versa. However, modern scientific developments can also lead to the erosion of traditional cultures, threatening the survival of Indigenous knowledge [13]. Therefore, it is essential to integrate traditional Indigenous knowledge with modern scientific knowledge [14], enhancing the subjectivity, uniqueness, practicality, and functionality of Indigenous cultures [15]. Mercer et al. found that integrating local knowledge with scientific knowledge can provide valuable information for disaster risk reduction and improve soil, fisheries, natural resource management, forestry, land management, health, agricultural research, marine conservation, climate change, desertification, and water resource acquisition in semi-arid environments [16]. However, there are few documented examples of integrating scientific knowledge with traditional local knowledge for tribal disaster education [17]. Thus, Indigenous disaster education should be based on traditional Indigenous knowledge and refined by integrating scientific knowledge.

Researchers point out that Indigenous knowledge systems in agriculture, astronomy, navigation, mathematics, medicine, engineering, military science, architecture, and ecology are rich in scientific thinking [18]. Problem-solving-oriented teaching often requires the application of cross-disciplinary knowledge rather than knowledge from a single domain, highlighting the integrative nature of traditional Indigenous knowledge and Indigenous science education. For example, when the Rukai make traps to catch wild boars and preserve meat (related to food acquisition and preservation for disaster preparedness), they apply scientific concepts like leverage principles and potential energy conversion to kinetic

energy, as well as mathematics (measuring branches for optimal elasticity) and engineering knowledge (trap stability). Thus, Indigenous disaster education should integrate science, technology, engineering, and mathematics (STEM) knowledge with traditional Indigenous knowledge through hands-on activities, enhancing learning interest, overcoming the low engagement of Indigenous students [19,20], and achieving the ideal outcomes of Indigenous sustainable education and development.

One study implemented a sustainability transdisciplinary education at the K-12 and university levels, and the results found that learners can acquire a deeper and broader understanding of how nature is influenced by people and human–environment relationships [21]. Similarly, STEM-based curricula developed for university students are also found to be beneficial for students' sustainability learning outcomes [22,23]. However, these studies primarily considered the effects of STEM-based sustainability curricula on cognitive outcomes for students above elementary school levels (e.g., [21–24]), and few studies have addressed how to better implement a sustainability STEM-based curriculum for young children. In the latest systematic review, it is found that less than ten studies involve young children at pre-school ages, and they primarily focus on STEM/STEAM-based curricula without a connection to sustainability. More surprisingly, among this very limited literature, there are also no studies that adopt suitable curriculum approaches for Indigenous young children (e.g., engaging young children in hands-on activities to solve real problems) to practice sustainability in their daily lives and to experience how people co-exist with their surrounding environment. The procedure that can be followed when kindergarten teachers encounter difficulties in developing STEM-integrated sustainability curricula and activities is also unclear [25]. Developing STEM-integrated Indigenous sustainability curricula and activities for Indigenous kindergarteners and their teachers based on theoretical frameworks and practical procedures may help fill this gap within the current literature.

Despite the importance and advantages of integrating STEM into Indigenous early childhood disaster education, there is a lack of STEM-related knowledge among early childhood teachers devoted to developing and implementing STEM-integrated curricula and activities [26–29]. As a result, STEM-integrated curricula and activities are rarely implemented in non-Indigenous kindergartens, let alone in Indigenous ones. Recent research has introduced a few examples where Indigenous culture has been integrated into early childhood STEM education. For example, one study integrated STEM education into the making of bird scarers in Bunun and Kanakavu cultures [30]. However, although the Rukai are one of the Indigenous tribes most threatened by natural disasters, there are no studies focusing on Rukai Indigenous sustainable development. Therefore, integrating STEM into Rukai early childhood disaster education to develop culturally sustainable curricula and teaching activities can provide valuable references for Rukai kindergarten teachers and support the sustainable transmission and development of Rukai traditional culture and knowledge.

In summary, Indigenous preschool teachers have no idea how to initiate a STEM-integrated sustainability curriculum based on Indigenous culture, or how to develop, organize, or implement related teaching activities. This study begins by examining traditional Indigenous culture and knowledge to establish the essence and framework of Indigenous early childhood disaster preparedness curricula and activities. It then explores the feasibility and benefits of integrating STEM into Indigenous disaster education. Finally, this study is devoted to achieving the following two main purposes:

- (1) To confirm the Indigenous knowledge dimensions and objectives suitable for developing STEM-integrated Rukai preschool disaster curricula and teaching for Indigenous young children.
- (2) To develop and provide examples for the future planning, design, and implementation of STEM-integrated Rukai or Indigenous early childhood disaster preparedness curricula and activities by focusing on the principles of developing and designing

STEM-integrated Indigenous early childhood disaster education, including setting educational goals, organizing curriculum content, and employing teaching methods.

2. Literature Review and Commentary

2.1. Indigenous Traditional Culture and Knowledge Frameworks with Sustainable Development Spirit

There is notable evidence to suggest that areas inhabited by Indigenous peoples are rich in linguistic, cultural, and biological diversity [31]. This richness results from the long-term practices embedded in the spirit of sustainable development found in traditional Indigenous culture and knowledge. However, there is a fundamental difference between the perspectives of Indigenous peoples and mainstream Western culture regarding sustainable development. Mainstream Western culture views sustainable development as ensuring the continuous supply of resources and services to support and enhance the well-being of individuals and human communities (e.g., improving social and individual economic health). In contrast, Indigenous peoples see sustainable development as the result of continuous and close reciprocal connections between people and communities and their surrounding ecological environment, which allows human culture to thrive [32]. Li believes that Indigenous peoples uphold a worldview based on animism and contextual knowledge, where cultural maintenance or change is dialectical, and life is closely linked to nature and the land, emphasizing community or collectivism over individualism; he believes that Indigenous peoples concern themselves with cultural sustainability, ethnic identity, and autonomy [33]. Thus, traditional Indigenous culture and knowledge can serve as the best example for countries worldwide of the practice of sustainable development themes (people, planet, prosperity, peace, and partnership). Analyzing the traditional culture and knowledge systems of Indigenous peoples helps with understanding the sustainable development spirit contained within them.

The Ministry of Education in Taiwan proposed the “110–114 Indigenous Education Development Plan”, incorporating “constructing Indigenous knowledge systems” as one of its core goals [34]. However, among known domestic studies, very few scholars have attempted to construct Indigenous knowledge systems or discussed and suggested methods for constructing Indigenous knowledge systems. Researchers have divided the knowledge systems of Taiwan’s Indigenous peoples into the following eight fundamental dimensions: ethnicity, society, economy, life, religion, law, education, and contemporary issues [35]. The ethnic dimension includes the history of ethnic groups, ethnic classifications, physical characteristics, and languages. The social dimension mainly refers to social organization; the economic dimension only refers to economic livelihood; and the life dimension includes housing culture, food culture, material culture, music and dance culture, medical culture, and life customs. The religious dimension includes cosmology, seasonal rituals, and myths and legends. The legal dimension includes customary law; the education and contemporary issues dimensions are further subdivided into specific components. One study divides the knowledge system of the Amis people into five basic aspects: food, clothing, shelter, education and entertainment, and crafts [30]. The “food” aspect includes production methods/food sources (including agriculture, fishing, hunting, animal husbandry, and gathering), types of food, food utensils, food preparation, food storage, dietary habits, and taboos. The “clothing” aspect includes clothing and accessories. The “shelter” aspect only includes buildings (including homes, sacrificial places, public and other buildings). The “education and entertainment” aspect includes music and dance, entertainment, and hobbies. The “crafts” aspect includes weaving, basketry, pottery, woodworking, wood carving, leather carving, boat building, and modern crafts. Another study also proposed a classification framework for the knowledge systems of Taiwan’s Indigenous peoples [36]. The author believes that Indigenous knowledge systems center on spirits, humans, and objects (CCK), and use twelve sub-core knowledge (SCK) dimensions (basic aspects), as follows: tribal/ethnic history, language, tribal/ethnic operational systems, cultural expression, transmission/education, livelihood, technology/crafts, healing, traditional territories/natural resources, law and rights, media, ethnic interactions, and others.

In summary, the Indigenous cultural and knowledge frameworks proposed by the above researchers have relatively low exclusivity and many basic dimensions. For instance, some researchers proposed eight basic aspects, among which society, economy, and life are highly correlated and less exclusive [35]. Similarly, one study distinguished between culture, society, and history [37], while another study proposed twelve basic dimensions, distinguishing between tribal/ethnic history and cultural expression, livelihood, and technology/crafts (multiple core knowledge elements or basic dimensions include different types of modern knowledge, but in practice, the same modern knowledge may be applied in different basic dimensions) [36]. Additionally, in the Amis knowledge system proposed by Zhu and Chen [38], the basic dimensions of food, shelter, and crafts also have high-correlation and low-exclusivity issues. Furthermore, some basic dimensions and content are not suitable for Indigenous disaster education (e.g., education and entertainment, political and judicial rights). Therefore, this study first preliminarily analyzes the relevant Indigenous literature to propose a simplified and less exclusive framework, using the traditional culture and knowledge of the Rukai Indigenous people as the basis for disaster education. The framework and content of the Indigenous disaster knowledge system are organized as shown in Table 1, which presents the preliminary development of Indigenous disaster education as structured around three highly exclusive basic dimensions. In terms of the basic dimensions of knowledge, these roughly correspond to the three core features of spirits, humans, and objects proposed by one researcher, as follows: “cultural and historical products, systems, and functions”, which includes myths and historical products related to disaster events, beliefs and rituals, and tribal systems; “observation, analysis, and prediction of natural phenomena and environments”, which includes observing and predicting natural phenomena such as climate, geology, hydrology, animal behavior, and plant growth, as well as observing, analyzing, and predicting the safety of locations and resource availability for disaster education; and the “acquisition, utilization, and management of natural resources”, which includes the acquisition and utilization of natural resources before and after disasters and the management of natural resources [36,39].

Table 1. Framework and content of Indigenous disaster knowledge system.

Knowledge Base Dimension	Knowledge Content
1. Cultural and Historical Artifacts, Systems, and Functions	1. Cultural and Historical Artifacts: (1) Historical facts, interpretations, and responses to natural disaster events. (2) Historical stories, myths, legends, songs, proverbs, and place names related to disasters. (3) Rituals related to disaster mitigation and avoidance.
	2. Systems and Their Functions in Disaster Prevention, Mitigation, and Reconstruction: (1) Family. (2) Tribal hierarchy. (3) Community halls. (4) Group organizations: family groups, fishing groups, hunting groups, labor exchange groups, etc.
2. Observation, Analysis, and Prediction of Natural Phenomena and the Environment	1. Climate. 2. Geology. 3. Hydrology. 4. Animal behavior. 5. Plant growth. 6. Site safety and resource availability.

Table 1. Cont.

Knowledge Base Dimension	Knowledge Content
3. Acquisition, Utilization, and Management of Natural Resources	1. Acquisition and Utilization:
	(1) Food production items, Gathering methods (including hunting, fishing, and farming), and tools.
	(2) Food processing and storage methods (e.g., pickling, smoking, drying, granaries).
	(3) Acquisition, utilization, and disaster prevention design for traditional building materials (e.g., fire resistance, water resistance, earthquake resistance).
	(4) Construction techniques for infrastructure and facilities (e.g., roads, agricultural embankments, water management).
	(5) Textile techniques.
	2. Management: Methods for maintaining and managing water sources, stone, timber, fishing grounds, hunting grounds, and farmland.

2.2. Feasibility and Benefits of Integrating STEM into Indigenous Disaster Education

One researcher noted that there are many differences and similarities between traditional Indigenous knowledge and Western scientific knowledge, with a close yet contradictory relationship between the two [40]. For instance, Western science emphasizes the universality or one-size-fits-all approach to knowledge, while Indigenous knowledge values the uniqueness and diversity among different Indigenous cultures [41]. Agrawal pointed out that Indigenous knowledge can improve modern scientific knowledge, which can enhance Indigenous knowledge [13]. However, Indigenous knowledge is also susceptible to loss due to the development of modern scientific knowledge, which threatens its continuity. Therefore, scholars argue that traditional Indigenous knowledge and modern scientific knowledge should not be distinctly separated, but that we should establish a bridge for communication between them to integrate the two [14]. This integration helps to strengthen the subjectivity, uniqueness, practicality, diversity, functionality, and applicability of Indigenous culture and knowledge [15]. Consequently, domestically and internationally, researchers have begun to promote Indigenous science education based on traditional Indigenous culture and knowledge (e.g., [18,42,43]).

Mercer et al. reviewed past studies and found that Western scientific knowledge can not only be integrated into the learning of Indigenous traditional culture and knowledge, but also often provides useful information for reducing disaster risks [16]. Carby also pointed out that numerous studies show that integrating Indigenous traditional knowledge and scientific knowledge helps improve issues such as soil management, fisheries, natural resource management, forestry, land management, health, agricultural research, marine conservation, climate change, and desertification [17]. However, examples of integrating scientific knowledge with Indigenous traditional knowledge for disaster education are still rare in the literature. Scholars in Taiwan have further noted that Indigenous school teachers and curricula seldom approach teaching from the perspective of ethnic culture and do not value its contribution to knowledge construction. This neglect results in poor learning outcomes for Indigenous students and low self-identity due to cultural disadvantages [44]. Therefore, Indigenous disaster education should be based on traditional Indigenous culture and knowledge and refined through the integration of scientific knowledge to enhance the learning outcomes of Indigenous students.

Snively and Corsiglia pointed out that the scientific thinking embedded in Indigenous agriculture, astronomy, navigation, mathematics, medicine, engineering, military science, architecture, and ecology is highly sophisticated [18]. This indicates that traditional Indigenous cultures possess rich interdisciplinary skills. In practice, Indigenous people often need to integrate interdisciplinary knowledge to solve problems encountered in daily

life. Therefore, in educational settings, the adoption of a teaching model oriented toward solving practical problems using interdisciplinary skills is recommended.

Globally, countries are currently working to promote interdisciplinary STEM education, which emphasizes the application of interdisciplinary knowledge and problem-solving through hands-on activities. This type of education is believed to enhance national competitiveness and increase learners' interest in learning [45,46]. Furthermore, it aligns with the spirit of Indigenous education or Indigenous science education curricula and the learning characteristics of Indigenous students, such as their preference for hands-on, concrete experiences and collaborative learning [47]. Thus, incorporating STEM into Indigenous disaster prevention education using hands-on activities to address local issues may help overcome the previously identified issue of low interest in curriculum learning among Indigenous students [19,20].

2.3. Principles for Developing and Designing STEM-Based Disaster Prevention Education for Indigenous Children

According to Article 6 of the Indigenous Peoples Education Act, governments at all levels should encourage schools to adopt teaching methods that cater to the cultural needs of Indigenous students, provide for their educational needs, and promote Indigenous and multicultural education [48]. The implementation of Indigenous education must be grounded in traditional cultural experiences. If the knowledge imparted by schools conflicts with or is unrelated to the cultural experiences of Indigenous learners, it can lead to educational frustration and a disordered perception of their own cultural values [49]. Consequently, Indigenous primary schools are increasingly implementing cultural curricula based on local Indigenous characteristics, and these cultural curricula can also serve as a reference for developing disaster prevention education programs.

Banks proposed four cultural curriculum models: the contribution approach, the additive approach, the transformation approach, and the social action approach [50]. The contribution approach emphasizes the contributions of Indigenous heroes and incorporates them, along with considerable holidays, festivals, and cultural artifacts, into the curriculum. The additive approach involves adding content related to the culture of a particular group to the existing curriculum without altering its structure, often presented as a unit or course. The transformation approach aims to fundamentally change the structure and essence of the existing curriculum by incorporating the perspectives, concepts, and issues of specific cultural groups. The social action approach focuses on addressing notable issues within the community through a cycle of practical action and reflection to find the best solutions.

In preschool education, which differs from other educational stages by not using subject-based teaching, an integrated learning approach is emphasized. Many preschools currently employ thematic teaching, where related concepts are derived from a central theme to design corresponding curriculum and teaching activities. For instance, a theme like "transportation" might lead to sub-concepts such as "types and functions of transportation". Teachers then design activities that help children understand these concepts.

Furthermore, disaster prevention education strongly emphasizes applying knowledge to solve real problems through practical action rather than merely learning about disasters and preventive measures through static classroom lectures. Elements of science, engineering, or mathematics within traditional Indigenous knowledge often require exploration through action [51]. Curiosity triggered by real problems is a key driver for learner engagement. Therefore, in the process of integrating STEM into preschool disaster prevention education, transformation and social action approaches should primarily be adopted.

The development and design of STEM-based disaster prevention education for young children should include setting educational goals, outlining curriculum content, organizing content, and selecting teaching methods. These aspects are described below.

2.3.1. Formulating Educational Goals and Curriculum Content

Bloom categorized educational objectives into three domains: cognitive, affective, and psychomotor. The cognitive domain is further divided into levels of increasing complexity, including knowledge, comprehension, application, analysis, synthesis, and evaluation. The affective domain includes receiving, responding, valuing, organizing, and characterizing. The psychomotor domain encompasses perception, set, guided response, mechanism, complex overt response, adaptation, and origination. Traditionally, educational objectives have been addressed by separate domains. However, since cognitive objectives can intersect with psychomotor objectives (e.g., “discerning colors through sensory perception” involves cognitive knowledge and psychomotor perception), a holistic approach to formulating objectives is recommended [51].

When developing teaching objectives for Indigenous preschool disaster prevention education, it is important to both follow general principles and articulate specific goals, for example, understanding the “lever principle” through hands-on activities. Therefore, objectives should integrate traditional Indigenous culture and knowledge with relevant STEM content.

A review of the existing literature reveals a scarcity of research on integrating STEM into Indigenous preschool disaster prevention education. Notable studies include Song’s examination of the implementation and effectiveness of integrating Indigenous culture into science education in a preschool in Nantou County, and Chen’s and Chen’s attempt to incorporate STEM concepts into preschool curricula for the Bunun and Kananavu tribes [52,53]. Song’s study listed separate objectives for Indigenous cultural and science curricula but only focused on science education goals. Chen’s and Chen’s research used a bird-scarer construction as an example of integrating STEM concepts into teaching activities, but the listed objectives did not address disaster prevention knowledge or curricula. This indicates a lack of specific, practical STEM teaching goals for preschool education in Taiwan [33].

In contrast, the US next-generation science standards (NGSS) clearly outline STEM educational goals and can serve as a reference for designing STEM-based disaster prevention curricula for Indigenous preschoolers (as shown in Table 2). The NGSS report details the STEM competencies expected at various educational stages, framed within three dimensions: disciplinary core ideas (DCIs), science and engineering practices (SEPs), and crosscutting concepts (CCs). These competencies emphasize practical application, requiring the integration of core ideas and CCs to solve problems. DCIs include physical science (PS), life sciences (LS), Earth and space sciences (ESS), engineering, technology, and the application of science (ETS). CCs include patterns; cause and effect; scale, proportion, and quantity; systems and system models; energy and matter; structure and function; stability and change; and the interdependence of science, engineering, and technology, among others. SEPs encompass asking questions; developing and using models; planning and conducting investigations; analyzing and interpreting data; using mathematics and computational thinking; constructing explanations and designing solutions; engaging in arguments from evidence; and obtaining, evaluating, and communicating information [54].

While NGSS provide detailed STEM standards, they lack specific references to traditional Indigenous culture and knowledge and do not fully address content applicable to preschool disaster prevention education. Thus, these STEM indicators need further adaptation to incorporate Indigenous cultural contexts and be translated into practical, age-appropriate STEM teaching objectives for Indigenous preschoolers. This adaptation will serve as a reference for developing STEM-based disaster prevention curricula and teaching activities in Taiwan.

Table 2. Suitable NGSS STEM indicators to be integrated into early childhood disaster prevention education.

STEM Fields	Corresponding Indicators
Science	• PS3-2-1: Understand that “sunlight warms the Earth’s surface”. • LS1-3-2: Understand that “plants need water and light to live and grow”. • ESS2-4-1: Understand that “weather is made up of sunlight, wind, snow or rain, and temperature at a specific time and place, and people measure these conditions to describe and record the weather, noting changes in weather patterns over time”. • ESS3-1-1: Understand that “living things need water, air, and resources from the land, and the places where they live provide what they need. Humans use natural resources to do many things”.
Engineering, Technology, and Application of Science	• ETS1-1-1: Ask questions, make observations, and gather useful information. • ETS1-1-2: Identify problems by asking questions and collecting information about situations people want to change, and define a simple problem that can be solved by developing new or improved objects or tools. • ETS1-2-1: Develop simple sketches, drawings, or physical models to illustrate how the shape of an object can help it function to solve a specific problem. • ETS1-3-1: Analyze data from two objects designed to solve the same problem and compare the advantages and disadvantages of each object.
Crosscutting Concepts	• CC1: Patterns. • CC2: Cause and effect. • CC3: Scale, proportion, and quantity. • CC7: Stability and change. • CC8: Interdependence of science, engineering, and technology. • CC9: Impact of engineering, technology, and science on society and the natural world.
Science and Engineering Practices	• SEP1: Asking questions and defining problems. • SEP2: Developing and using models. • SEP3: Planning and carrying out investigations. • SEP4: Analyzing and interpreting data.

2.3.2. Organization of Curriculum Content

Scholars, domestically and internationally, have different perspectives on organizing Indigenous cultural curriculum content. Zhou used an interview method to outline Indigenous cultural curriculum content for elementary education, organized in a “parallel listing” manner, and matched these content areas with corresponding curriculum themes, as shown in Table 3 [49]. In contrast, the Alaska native knowledge network has developed a spiral curriculum based on the principles of “vertical coherence and horizontal integration”. This curriculum progresses from the familiar (personal experiences) to the more distant, gradually expanding in knowledge breadth. It includes 12 curriculum areas, organized in the following order: family, language/communication, cultural expression, tribe/community, health, living in place, outdoor survival, subsistence, the Alaska Native Land Claims Settlement Act, technology/technical applications, energy/ecology, and exploring horizons [40].

The concept of family heritage refers to all family members from the past to the future. Individuals need to understand their roles and responsibilities within the family. Genealogical charts help children understand their kinship system and blood relations, fostering a sense of pride in themselves and their culture through ancestral worship.

The essence of the language/communication curriculum area is understanding the importance of language in cultural transmission and continuity. The cultural expression theme focuses on comprehending the wisdom embedded in a culture. The tribe/community aspect focuses on the importance of completing tasks through cooperation within a tribe or community. The health theme emphasizes the importance of creating a healthy tribal environment for children. Local life emphasizes the significance of elders for knowledge

and cultural transmission. The wilderness survival aspect stresses understanding one's environment through honesty, humility, and humor, and sharing resources with those who lack them.

Table 3. Indigenous cultural education curriculum content, themes, and learning areas.

Curriculum Content	Themes	Learning Areas
Indigenous Language and Literature	Myths, legends, poetry, drama	Language, Arts and Humanities
Ethnic History	Migration, battles, intertribal relations	Language, Arts, Social Studies
Customs and Rituals	Naming, coming-of-age ceremonies, festivals, funerals	Arts and Humanities, Social Studies
Indigenous Cuisine	Dietary habits, staple foods, plant cultivation, cooking	Social Studies, Natural and Life Sciences
Indigenous Music and Dance	Dance, music, instruments, folk songs	Arts and Humanities, Language, Arts
Indigenous Crafts	Carving, pottery, weaving, clothing, totems	Arts and Humanities, Natural and Life Sciences, Technology
Indigenous Science	Mathematics, natural science, architecture	Natural and Life Sciences, Arts and Humanities, Mathematics
Natural Ecology	Human geography, animals, plants, restoration	Natural and Life Sciences, Social Studies
Physical Activities	Sports competitions, hunting, health care	Health and Physical Education, Social Studies
Kinship Systems	Kinship relations, blood ties	Social Studies, Comprehensive Activities

The essence of the Alaska Native Claims Settlement Act theme is ensuring that Indigenous people recognize the importance of this legislation, as it guarantees their autonomy, prevents arbitrary land destruction, and reflects their cooperative and tolerant attitudes and persistence. Through co-management mechanisms, natural ecology can be perpetually nurtured under Indigenous care. The theme of technology/technical application emphasizes utilizing natural resources and improved tools, enabling Indigenous people to survive and adapt to changes in their living environment. The energy/ecology theme aims to ensure that students understand that nature provides everything humans need, and they must respect all that nature offers. The exploring horizons aspect stresses the importance of mutual respect in Indigenous cultural values, fostering a mutual understanding and appreciation of each other's cultures to create a harmonious and prosperous atmosphere.

Bruner's spiral curriculum concept involves repeatedly revisiting the same topics or concepts. Subsequent courses deepen knowledge about previous subjects. The spiral curriculum has four main characteristics: revisiting previously learned topics, concepts, or abilities; gradually increasing the difficulty of learning objectives to guide students to achieve the final overall goal; new learning experiences related to old ones; and students' abilities gradually increasing as the course progresses. Therefore, the spiral curriculum implicitly includes the "reinforcement principle" (continuously reinforcing previously learned knowledge or concepts), the "principle of progression from simple to complex" (students gain a deeper understanding by exploring the same topic or concept), the "integration principle" (vertical and horizontal integration of knowledge), the "logical continuity principle", the "high-level goal-guided principle" (guiding learners to reapply previously learned knowledge for deeper learning), and the "flexibility principle" (allowing learners who have mastered primary knowledge or concepts to enter the learning spiral of higher-level knowledge or concepts) [55,56].

A Taiwanese researcher proposed a more specific "spatial map", similar to the Alaskan Native Knowledge Network spiral curriculum (as shown in Figure 1). Starting from the learner's recent family or personal experiences and environment, learning experiences expand to the outer environment (such as farmlands, hunting/fishing grounds, and even

sacred spaces and surrounding natural environments), serving as a reference framework for organizing curriculum and teaching activities [57]. The Alaskan Native Knowledge Network spiral curriculum specifically mentions the increasing breadth and depth of knowledge within the same topic, with logical coherence between knowledge points. Therefore, this study adopts the concepts of the Rukai scholar Tai-ping and the Alaskan Native Knowledge Network spiral curriculum to organize the goals of integrating STEM into early childhood disaster education and the content involved.

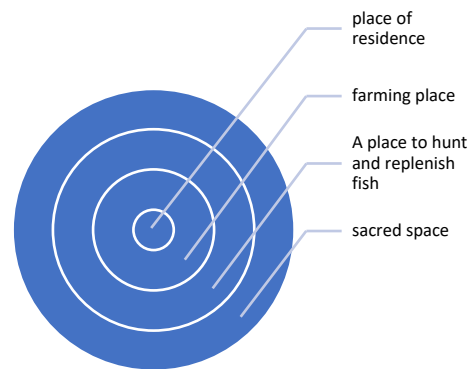


Figure 1. Rukai spatial map.

2.3.3. Teaching Methods Utilization

Hewson pointed out that integrating traditional Indigenous knowledge into science curricula and teaching activities can follow the Tyler teaching model [58]. During the curriculum implementation phase, six steps can be followed, as shown in Table 4.

Table 4. Tyler teaching model.

Step	Content
Preparation	Teachers need to guide students to focus on the course content through pre-class preparation, which helps with the retrieval of knowledge in the long-term memory. Additionally, teachers must create a friendly, focused, and respectful environment.
Questioning	Before teaching, teachers can use classroom Q&A or learning tasks to understand students' knowledge and skills related to the course topic. This helps teachers identify students' learning needs, experiences, and interests related to the learning topic.
Providing Feedback	Teachers should give students immediate positive and negative feedback. Most importantly, teachers must decide how to proceed with the lesson based on the knowledge, experiences, and interests exhibited by the students.
Instruction	Based on students' needs and the curriculum plan, teachers should use various teaching methods (e.g., experiments, projects, short lectures, demonstrations, role-playing, argumentation teaching, case studies, problem-based learning, and simulations) to provide instructional guidance to students.
Application	Teachers help students apply new knowledge and skills to focus on problems, such as using knowledge about photosynthesis to maintain a garden or farm.
Review	After the lesson, teachers should check students' knowledge acquisition by, for example, inviting students to summarize what they have learned in the lesson.

In addition to the Tyler teaching model, researchers have proposed the five-phase learning cycle. This is suitable for designing science curricula for young children and can also serve as a reference for integrating STEM into early childhood disaster education courses. The five phases are presented in Table 5 [59].

Song found that when preschool teachers used the five-phase learning cycle for instruction, children made considerable progress in understanding their tribe's traditional history, community location, traditional lifestyle, and culture [52]. Additionally, they showed increased interest in learning about tribal myths and legends, customs and rituals,

traditional culture, and artistic content. Furthermore, there were notable improvements in their understanding of the physical characteristics of plants and animals, weather changes, motion phenomena, natural science phenomena, and the similarities and differences of materials, as well as in their observational skills.

Table 5. Five-phase learning cycle.

Step	Content
Engagement	Teachers attract learners' attention and stimulate their thinking through books, flashcards, videos, or other examples.
Exploration	By guiding learners with open-ended questions, they are encouraged to think, plan, investigate, and organize information, triggering active exploration. Learners are allowed to try and experiment in various ways, learning by doing.
Explanation	Discuss and reflect on the exploration process and results from the previous stage, understanding concepts through re-experiments and discussions.
Application	Teachers provide opportunities for young children to apply new concepts through hands-on activities or experiments, helping them more clearly understand the principles of how concepts work.
Assessment	Through diverse assessment methods, teachers understand learners' learning conditions, for example, using portfolio assessment and performance assessment to gauge learners' interests and learning effectiveness.

Due to the high similarity in content between the two models and the fact that researchers in our country have used the five-phase learning cycle as a reference for designing Indigenous preschool cultural science curricula and teaching activities, it is highlighted that this model is more suitable as a teaching method for integrating STEM into Indigenous preschool disaster education curricula. Therefore, this study adopts the five-phase learning cycle as the main reference teaching method when integrating STEM into Indigenous preschool disaster education curricula.

3. Research Methods

3.1. Research Setting, Participants, and Process

We adopt ethnography as a research method to achieve the purposes of this study. Ethnography is to study people in a natural setting or field by means of methods to capture their social meaning and common activities by involving the researcher participating in that setting or field [60]. Methods used in ethnography include interviews, observations, participation, and listening [61]. This study was conducted with Rukai tribal communities and preschools in Kaohsiung and Pingtung. First, the relevant Indigenous literature was reviewed to construct a framework for Indigenous disaster knowledge and corresponding curriculum and teaching activities. Based on this framework, a corresponding interview outline was designed (the interview outline contains extensive content and is not the main focus of this article, so only the knowledge dimensions and content related to this article are listed in Table 6).

Table 6. Rukai tribe disaster prevention knowledge interview outline.

Knowledge Dimension	Knowledge Content	Interview Outline
Acquisition, Utilization, and Management of Natural Resources	• Acquisition and utilization: ▪ Food production items and collection methods. ▪ Food preparation and storage methods.	▪ How do you acquire food during a disaster? What types of food are produced, and how are they obtained? ▪ How is food prepared and stored during a disaster?

In-depth interviews were conducted with eight members of the Rukai tribes in Kaohsiung and Pingtung, along with disaster relief and education experts, with the aim of achieving the first objective of this study. Then, according to the curriculum development and design principles derived from the relevant literature, discussions were held with four preschool teachers from the Rukai tribal communities on how to effectively integrate STEM knowledge into Rukai disaster education curriculum and teaching activities. Finally, close observations were conducted to record the implementation of the curriculum and teaching activities in practice. The aim of this approach was to efficiently develop and implement Rukai disaster education curricula and teaching activities in order to achieve the second objective of this study.

3.2. Research Tools

The main research tool for this study was a semi-structured interview outline, designed based on Rukai disaster education content and constructed through interviews with Rukai tribal members and disaster relief and education experts. The interview outline is shown in Table 7 and focused on the following points:

- A. Choosing Teaching Themes.
- B. Organizing Teaching Themes and Content.
- C. Setting Goals for Integrating STEM into Rukai Disaster Education Curriculum and Teaching.
- D. Adopting Appropriate Teaching Methods.

Table 7. Interview guide for developing and implementing Rukai tribe disaster prevention curriculum and teaching activities.

Interview Highlights	Interview Highlights
Selecting Teaching Topics	Which of these Rukai tribe disaster prevention education topics do you think is most closely related to the daily experiences of Rukai children and aligns with the Indigenous emphasis on sustainability?
Organizing Teaching Topics and Content	How should disaster prevention education topics be arranged and organized in relation to Rukai children's daily experiences? How should the distance of these experiences be considered in planning the teaching topics and content?
Setting STEM Integration Goals for Rukai Tribe Disaster Prevention Curriculum and Teaching	For each teaching topic, how can Rukai disaster prevention knowledge be integrated with STEM competencies when setting curriculum and teaching objectives?
Employing Appropriate Teaching Methods	How should teaching activities and content be designed and implemented for each of the five stages of teaching (guided participation, exploration, explanation, application, and assessment)?

These focal points aim to ensure a comprehensive approach to developing and implementing an effective Rukai disaster education curriculum that is integrated with STEM.

4. Development and Implementation of STEM-Integrated Rukai Preschool Disaster Education Curriculum

4.1. Identifying Indigenous Knowledge Dimension and Objectives Suitable for Developing STEM-Integrated Rukai Preschool Disaster Curriculum and Teaching for Indigenous Young Children

The development of the STEM-integrated Rukai preschool disaster education curriculum is based on the traditional disaster-related knowledge within Rukai culture. The curriculum implementation approach follows the principles of transformation and social action, using the NGSS STEM standards as the foundation for setting teaching objectives. The organization of teaching activities adheres to the principles of the spiral curriculum, including reinforcement, progression from simple to complex, integration, logical continuity, high-level goal guidance, and flexibility. The teaching method employed is the five-phase learning cycle.

After discussions and interviews with four preschool teachers from Rukai tribal communities, it was unanimously agreed that the knowledge dimension of the “acquisition, utilization, and management of natural resources”, particularly the growth, utilization, and management of plants, is closely related to the life experiences of Rukai preschoolers. This finding suggests that topics related to environmental and life science may be the most suitable sustainability topics for early childhood STEM education, which is consistent with the results of a former review study synthesizing articles on Western early childhood education for sustainability [24]. Therefore, the development and design of the STEM-integrated Rukai preschool disaster education curriculum are based on this knowledge content.

Given that all the preschool teachers pointed out that millet and red quinoa are important and common food crops traditionally used in Rukai disaster prevention, and due to space limitations, this paper will focus on the teaching activity “Millet and Red Quinoa Grow Fast” as an example. This activity illustrates STEM teaching objectives and the design and implementation process.

Due to the lack of specific and concrete STEM teaching objectives or indicators in Taiwan, and the lack of clarity in the teaching objectives proposed by relevant researchers, we used relatively clear STEM standards provided by the NGSS. However, these standards are still not specific enough for preschoolers. For example, the life sciences standard LS1-3-2, “Understand that plants need water and light to survive and grow”, is concrete. In contrast, standards in the fields of engineering, technology, and science application (e.g., asking questions, making observations, and collecting useful information), cross-disciplinary concepts (e.g., form), and scientific and engineering practices (e.g., asking questions and defining problems) lack specific descriptions [54].

Therefore, after discussion with the Rukai preschool teachers, the researchers adapted the NGSS STEM standards to incorporate Rukai traditional disaster knowledge content. This adaptation led to the development of specific teaching objectives for the STEM-integrated Rukai preschool disaster education curriculum and teaching activities, as shown in Table 8.

Table 8. Teaching objectives for integrating STEM into disaster prevention education for Rukai tribe children.

STEM Fields	STEM Teaching Objectives
Science	• PS3-2-1: Understand that “sunlight warms the Earth’s surface, creating a suitable environment for the growth of millet and quinoa”. • LS1-3-2: Understand that “millet and quinoa need water and sunlight to grow and survive”. • ESS3-1-1: Understand that “millet and quinoa need water, air, and resources from the land to grow, and that Indigenous people consume millet and quinoa for sustenance”.
Engineering, Technology, and Science Applications	• ETS1-1-1: Ask questions, observe, and collect information that helps in the growth of millet and quinoa. • ETS1-2-1: Use drawings to represent the ideal growth environment for millet and quinoa, and discuss solutions with other children to improve their growth environment.
Crosscutting Concepts	• CC1: Observe or identify weather patterns in the mountains. • CC2: Understand the causes of growth and death of millet and quinoa. • CC3: Understand the stability and variability of the growth environment for millet and quinoa. • CC9: Use television or the internet to collect weather information to create or maintain conditions favorable for the growth and survival of millet and quinoa, while avoiding unfavorable conditions.
Science and Engineering Practices	• SEP1: Know the quantity of millet and quinoa in different fields and how much water to apply to prevent them from dying. • SEP2: Present the ideal process for caring for millet and quinoa using a planting step diagram. • SEP3: Follow the designed planting step diagram to care for and cultivate millet and quinoa.

4.2. Organizing Curriculum with Teaching Methods into Implementation Process

4.2.1. Engagement

In accordance with the suggestions proposed by former studies, the Indigenous preschool teachers developed and implemented the STEM-integrated curriculum and teaching activities based on the hands-on principle to engage Indigenous young children [19,20]. The teacher leads the children to observe the edible plants planted in the tribe and compare areas with sunlight and without sunlight, asking them to note the differences. After returning to the classroom, the teacher and the children discuss their observations.

The “Grow Fast, Millet and Red Quinoa” teaching activity begins with a video showing the previous process of planting millet and red quinoa to capture the children’s attention and interest. The following questions are then used to connect their prior experiences with new ones:

A. Share Planting Experiences:

The teacher asks the children to share their experiences planting on another plot of land and how they cared for the millet and red quinoa (the teacher records the children’s responses on the whiteboard).

B. Discuss Reasons for Previous Failures:

The teacher discusses with the children the possible reasons why the millet and red quinoa planted on the previous plot failed (the teacher helps the children summarize the important conditions for the growth of millet and red quinoa on the whiteboard).

C. Share Current Planting Experiences:

The teacher asks the children to share their experiences of planting on the current land and how they are caring for the millet and red quinoa (the teacher records the children’s responses on the whiteboard).

D. Compare Planting Conditions:

The teacher and the children discuss and compare the conditions (sunlight, air, water, soil, or temperature) of the previous and current planting environments.

4.2.2. Exploration

The teacher and the children discuss the importance of millet and red quinoa in traditional Rukai daily life and for disaster prevention. Then, they explore the differences between areas with and without sunlight and their effects on plant growth. This helps the children understand the following concept: “PS3-2-1: Sunlight warms the Earth’s surface, creating an environment suitable for the growth of millet and red quinoa”. They also address the engineering, technology, and science application standard ETS1-1-1 by asking questions, making observations, and gathering information that supports the growth of millet and red quinoa [54].

Using the principles of the spiral curriculum—reinforcement, progression from simple to complex, and integration—the teacher asks the children to recall their past experiences with planting. They share their planting stories and analyze the reasons for their success or failure. The discussion focuses on identifying the necessary conditions for the growth of millet and red quinoa. The children learn that, in addition to sunlight, these plants also need water and soil, and water is related to changes in climate and weather. This helps them grasp scientific concepts such as “LS1-3-2: Plants need water and light to live and grow” and “ESS3-1-1: Plants need water, air, and resources from the land to grow. Indigenous people use millet and red quinoa for sustenance”.

Next, they discuss the optimal conditions for planting millet and red quinoa: how much can be planted on a plot of land, the duration of sunlight, and the amount of water needed. The children draw pictures of what they believe to be the best conditions for the growth of these plants. The teacher consolidates these ideas (as shown in Figure 2), fulfilling the engineering, technology, and science application standard “ETS1-2-1: Use drawings to

express the ideal growth environment for millet and red quinoa”, encouraging discussions on improving growth conditions. They also adhere to SEP2 by creating a step-by-step planting diagram to illustrate the ideal care process, and SEP3 by implementing these steps in their planting activities.

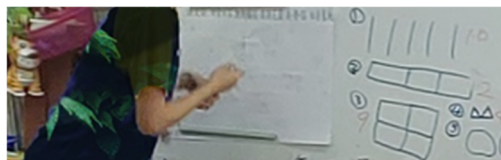


Figure 2. Teachers and Rukai children discuss suitable planting conditions for millet and red quinoa.

Finally, each group of children engages in an actual planting activity based on the optimal growth conditions they proposed.

During the planting activity, each group of children records their daily observations and collects data, including weather conditions, watering amounts, sunlight exposure, and the growth status of the millet and red quinoa. This practice reinforces several CCs:

- CC1: Observing Weather Patterns: The children can observe and identify weather patterns in the mountains.
- CC2: Understanding Growth and Death Factors: They learn to understand the reasons behind the growth or death of millet and red quinoa.
- CC3: Stability and Change in Growth Conditions: The children grasp the stability and changes in the growth environments of millet and red quinoa.
- CC9: Utilizing Technology for Weather Information: They collect weather information through television or the internet to create or maintain conditions conducive to the growth and survival of millet and red quinoa and to avoid unfavorable conditions.

4.2.3. Explanation

Each week, during two afternoon sessions lasting 30–40 min each, groups of children will participate in discussions where they share their observations. They will also reflect on whether any issues have arisen in their planting plans that may require adjustments. For example, the children might observe that recent rains in the mountains have made the soil too wet, which could hinder the growth of millet and quinoa. They might then decide to reduce the frequency and amount of watering. The children will then be asked to try this adjusted method to clarify the actual impact of water levels on the growth of millet and quinoa.

4.2.4. Application

The teacher will introduce the concept of measurement to the children, teaching them how to use formal measuring tools to improve their planting outcomes. This will help the children understand that appropriate watering supports the growth of millet and quinoa, while excessive watering may cause the plants to die. Additionally, the children will be taught to use weather forecasts to anticipate future weather conditions and adjust their watering accordingly (e.g., avoiding watering on rainy or cloudy days or reducing watering the day before). Finally, the children will apply this new knowledge to adjust their planting activities, record daily weather and water usage, and implement the high-level goals of the spiral curriculum, guided by the principles of flexibility and continuous learning.

4.2.5. Assessment

Both portfolio assessment and performance-based assessment were used. Through children’s observation records, planting procedure drawings (sequentially from digging, establishing and stirring potting soil, steeping the seeds, dividing the land into groups, putting the seeds into separate lands, and caring for the seeds/plants), photos, and notes from group discussions, the teacher will assess how well the children collect and utilize

information about the growth of millet and quinoa and whether they can effectively apply this information to improve plant growth.

In summary, it is found that young children were not only more engaged in this teaching and learning process, but also acquired a deeper and broader understanding of how nature is influenced by people and human–environment relationships. These results correspond to former studies [21,45,46]. In addition, young children also gain the ability to put sustainability development into practice, with similar findings to former studies that demonstrated that university students' sustainability learning outcomes can be enhanced through STEM-based curricula [22,23]. For example, young children can learn from previous failures and incorporate STEM knowledge to avoid the conditions that harm the growth of the plants (e.g., pay attention to the weather through either observation or weather forecasting to prevent wasting too much water on plants and causing their death). Most importantly, Indigenous preschool teachers who are initially afraid of their inability to develop and implement STEM-integrated Indigenous curricula and teaching activities for sustainability, as demonstrated in several studies [26–29], increasingly become confident in undertaking this because frameworks, principles, and specific procedures can be followed and co-developed through discussions. This may shed light on the importance of the proposed framework, principles, and specific procedures in promoting not only teachers in teaching STEM-integrated Indigenous curricula and teaching activities for sustainability, but also young children in putting sustainability development into practice through applying learned STEM knowledge.

5. Conclusions and Recommendations

5.1. Conclusions

Traditional Indigenous culture and knowledge embody a sustainable development ethos that differs from the Western mainstream and has been practiced for centuries. These cultural and knowledge bases can serve as valuable references for other cultures in implementing sustainable education. The increasing severity of climate change has considerably heightened the frequency and impact of natural disasters in Taiwan, affecting all communities, with Indigenous mountain tribes (such as the Rukai people) being particularly vulnerable due to their smaller populations. Understanding and implementing the disaster preparedness knowledge of the Rukai people can help mitigate the adverse effects of disasters on human life and reduce the threats they pose to survival. There are currently few disaster preparedness curricula and teaching activities aimed at sustainable development in Taiwan, particularly in early childhood education. The development and implementation of the STEM-integrated disaster preparedness curriculum for Rukai preschoolers presented here can serve as a reference for Rukai tribal preschool teachers, as well as for other Indigenous and non-Indigenous preschool educators planning to implement similar STEM-integrated disaster preparedness curricula. More importantly, starting disaster education early helps foster concrete sustainable development practices later in life. Implementing these in Indigenous areas also contributes to the revitalization and continuation of Indigenous cultural heritage, making it essential to root early childhood/Indigenous early childhood disaster education at the foundational level.

In the current context, where traditional Rukai knowledge is rapidly disappearing due to human factors (such as the outmigration of Rukai youth and their children) and natural factors (such as village relocations due to typhoons), the urgency of promoting Rukai early childhood sustainable education to revive and pass on Rukai traditional culture and disaster preparedness knowledge cannot be overstated. Given the lack of sustainable education curricula and activities for Indigenous early childhood education in Taiwan, and recognizing that Western STEM knowledge can complement traditional Indigenous knowledge, this study provides the following recommendations for future research and teaching practice based on the development and implementation of early childhood disaster preparedness curricula and activities in Rukai communities.

5.2. Recommendations

5.2.1. Develop Teaching Objectives for STEM-Integrated Indigenous Early Childhood Sustainable Education Based on Traditional Indigenous Culture and Knowledge

Indigenous peoples have made invaluable contributions to the preservation of land and the continuation of human culture over millennia, showcasing the sustainable development wisdom inherent in their traditional culture and knowledge. However, this wisdom has often been overlooked by mainstream culture. Additionally, Indigenous peoples, who have contributed the most to sustainable development, must endure the dual threats to their cultural survival of extreme weather caused by environmental degradation by mainstream culture and the challenges posed by mainstream culture's highly developed state. Therefore, it is urgent to begin disaster preparedness education and instill the rich, sustainable wisdom of traditional Indigenous culture and knowledge in children from an early age. Although this paper uses Rukai disaster preparedness knowledge as a foundation for constructing an early childhood disaster preparedness curriculum, the traditional knowledge of other Indigenous tribes also includes the application of interdisciplinary skills (such as using scientific principles like force and motion, applying mathematical knowledge, improving engineering techniques to enhance hunting traps, increasing food acquisition, and extending food preservation through drying or pickling methods). These elements align well with the recent global push for STEM education. Integrating STEM with traditional Indigenous culture and knowledge can generate innovative solutions to the challenges encountered in implementing sustainable development through disaster preparedness education.

Since the STEM indicators developed by NGSS are neither directly aimed at sustainable development nor incorporate the sustainable spirit and content inherent in traditional Indigenous culture and knowledge, they do not provide specific teaching objectives for the development of Indigenous sustainable curricula and activities. Although Taiwan has developed "Preschool Curriculum Guidelines" for early childhood education, the goals (e.g., collecting information on natural phenomena) and learning indicators under them (e.g., observing changes in the characteristics of natural phenomena) lack specific content. In addition, since these guidelines are also developed based on mainstream culture, they do not cover the essence of traditional Indigenous culture and knowledge, nor do they embody the spirit of sustainable development. In the absence of specific, actionable teaching objectives, STEM-integrated Indigenous early childhood sustainable education remains relatively rare in Taiwan; therefore, developing teaching objectives for such education based on traditional Indigenous culture and knowledge is crucial for promoting Indigenous sustainable education in the country.

5.2.2. Formulate Themes for Indigenous Early Childhood Sustainable Education Activities Based on Recent Experiences, Using Transformative and Social Action Approaches to Reform Preschool Curriculum Practices

The saying "food is the most important thing to the people" underscores the importance of food for cultural survival. This is especially true in Indigenous areas, where food production and acquisition are more challenging and susceptible to natural disasters. Therefore, sustainable education, which balances environmental and species protection, is a critical component of Indigenous education. For Indigenous preschoolers, planting traditional crops suitable for their living environment not only aligns with their daily experiences, but also supports the transmission of traditional Indigenous culture and knowledge, as well as the goals of environmental sustainability education. Additionally, mainstream early childhood education tends to emphasize static indoor activities (e.g., building with blocks, imaginative play, arts and crafts, and teacher-led instruction), with outdoor activities mostly limited to large motor skills exercises like running, rhythm exercises, gymnastics, or using playground equipment. There are few opportunities for children to think critically and to take action to solve real-life problems. Given the unique cultural and environmental context of Indigenous communities, where traditional culture and knowledge have historically been passed down through solving practical issues, a transformative approach

is needed to change the nature of Indigenous early childhood education. This approach should incorporate social action strategies that address environmental protection (e.g., soil and water conservation) and food acquisition challenges. By engaging in hands-on outdoor planting experiences, children can develop an understanding of the relationship between humans and the natural environment, fostering a sense of responsibility for environmental protection. This approach also helps cultivate an appreciation for Indigenous culture and knowledge, as well as the benefits of applying interdisciplinary skills to solve real-world problems, ultimately supporting the goals of sustainable education rooted in traditional Indigenous culture and knowledge.

5.2.3. Integrate Spiral Curriculum Principles into the Five-Stage Learning Cycle to Revisit, Deepen, and Broaden Learning Experiences

Due to the nature of the curriculum and teaching activity themes, as well as the fact that most Indigenous preschoolers have had limited prior experience with planting, this study applied the principles of reinforcement, simplicity to complexity, and integration to the second stage of the five-stage learning cycle (i.e., the exploration stage). Through post-observation discussions and reflections on their actual planting experiences, children repeatedly revisited the idea that conditions suitable for plant growth involve not only sunlight and water, but also the interplay of soil and other factors. This process helped children understand the importance of adjusting to actual conditions as these variables change. The practical implementation of the curriculum and teaching activities can be adjusted according to the Indigenous preschoolers' familiarity with the subject and the current stage of the curriculum. For example, if Indigenous preschoolers have previously learned how to improve the planting process through formal measurement, the principles of reinforcement and/or simplicity to complexity can be integrated into the first stage of the learning cycle (i.e., engagement), continuing to strengthen the children's measurement skills. In the second stage, the principle of integration and/or logical continuity can be incorporated. Higher-level goal-guiding and flexibility principles are more suitable for the third (explanation) and fourth (application) stages of the learning cycle, where children discuss the problems they encounter and reflect on possible solutions. Teachers can also introduce new methods for solving these problems, guiding children who have already mastered previous knowledge and concepts to use new methods to solve problems and evaluate their effectiveness. This forms the basis for refining solutions and advancing personal knowledge and skills.

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