Universal and Equal Aspects of Science Education in Taiwan

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1. Introduction

Science education plays a pivotal role in fostering a country's scientific prowess and serves as the bedrock for its path towards industrialization, technological advancement, and modernization. Consequently, all nations place significant emphasis on the importance of science education. In recent years, enhancing scientific literacy has emerged as a crucial objective that governments and international organizations are actively dedicated to promoting (AAAS, 1989; Chin, 2007, Ministry of Education, 2014, 2018; National Research Council, 1996; OECD, 2015, 2018).

With this objective in mind, the target audience for science education should be everyone, without differentiation based on factors such as region or ethnicity. Therefore, this article elaborates from the perspectives of formal and informal education, illustrating Taiwan's efforts in the development of science education through different types of educational approaches. It further explains how Taiwan ensures the universality and equal opportunities of science education, especially for traditionally marginalized groups. Lastly, the article provides recommendations for the future advancement of science education.

2. The History of Science Education in Taiwan

Science education in Taiwan has its roots in the Science Education Committee of the Ministry of Education, which was established in 1954. Over the years, it has evolved into a well-structured and professional learning system, with a primary focus on science education within schools. The curriculum content has been continuously adapted to align with Taiwan's industrial development and transformation process. The following section outlines the significant curriculum transformations and adjustments in Taiwan.

(1) Nine-year Compulsory Education

Prior to 1968, Taiwan's compulsory education was limited to 6 years, and after completing elementary school, individuals had the option to forego secondary school education. This system led to a generally low level of knowledge among the population and had negative implications for the country's overall development. To

address these challenges, former President Kai-shek Chiang initiated the Nine-year Compulsory Education Policy with the aim of elevating the nation's knowledge level and equipping individuals with specialized skills to meet the demands of national development.

This policy has also resulted in the cultivation of a substantial pool of middle-level talents, facilitating Taiwan's smooth transition from an agricultural society to an industrial and commercial one. The extension of compulsory education has ensured a sufficient workforce to support national development during the process of industrial transformation and has established a strong foundation for further advancement into the high-tech industry in the future.

(2) Grade 1-9 Curriculum Guidelines

In response to the challenges posed by the new generation in the 21st century and to align with education reforms worldwide, Taiwan implemented the Grade 1-9 Curriculum Guidelines in 2001. The goal was to enhance the overall quality of its citizens and bolster national competitiveness. This curriculum reform comprised three main components.

A. Continuity of Elementary and Junior High School Curriculum

In the past, the elementary and junior high school courses had a consistent time frame, but they were designed and planned independently, resulting in a disconnect between their content. This approach created a gap in the curriculum, leaving students feeling frustrated during the learning process. To address this issue, the current curriculum reform integrates the curriculum of elementary and junior high schools, ensuring a more coherent and seamless learning experience for students. This emphasis on curriculum design for the entire learning stage marks the first time such an approach has been adopted in Taiwan.

B. Incorporate the concept of humanistic care

The educational focus in Taiwan has historically been centered on cognitive learning, elevating our students to a global pinnacle in terms of academic proficiency. However, this approach has also resulted in a lack of environmental and societal concern among students. To address this issue, the current curriculum reform has incorporated a dimension of social concern. In the realm of natural science courses, the theme of "Science and Society" which is further divided into three sub-themes: the

development of science, the beauty of science, and the ethics of science has been introduced. This curriculum design aims to foster a balanced scientific attitude in students and encourage them to reflect on the relationship between science and society. By doing so, science and society are interconnected, rather than viewed as two completely independent contexts. The intention is to bridge the gap between scientific knowledge and its societal impact, enabling students to appreciate the value of science in addressing real-world challenges and promoting environmental consciousness.

C. Issue teaching that matches the pulse of society

Owing to societal changes and the rapid advancement of information and communication technology, problem-solving now requires interdisciplinary and cross-disciplinary approaches. In response to this, the curriculum reform has integrated vital topics aligned with real social situations into the curriculum. The aim is to enable students to develop problem-solving skills that transcend disciplinary boundaries through topic-based teaching. This curriculum reform encompasses six major issues, namely gender equality education, environmental education, information education, human rights education, career development education, and marine education. By incorporating these topics, teachers and students can relate the knowledge acquired in natural science courses to their daily lives through practical discussions. This approach fosters a connection between learning and everyday experiences, thereby enhancing students' interest and motivation in the learning process.

(3) Curriculum Guidelines of 12-Year Basic Education

As the world progresses, knowledge is becoming increasingly specialized, the division of labor is becoming more refined, and the expectations for the quality of individuals are rising. To meet these challenges, Taiwan has undertaken a curriculum reform known as 12-Year Basic Education. The most significant change in this reform is the integration of literacy into the curriculum, aligning with the OECD declaration. The reform aims to foster holistic learning by combining knowledge, skills, and attitude, and applying them practically, empowering students to become lifelong learners who take autonomous action, engage in effective communication and interaction, and actively participate in real-life scenarios.

To attain the aforementioned objectives, this curriculum has introduced "Inquiry and Practice" courses in Nature Science and Social Studies in high school. By

structuring the course around four stages: observation, planning and implementation, demonstration and modeling, and expression and sharing, students are encouraged to adopt a system mindset. These courses are regarded as a vital element in cultivating students' higher-order thinking abilities.

Based on the overview of Taiwan's curriculum reform process and natural sciences, it is evident that the country's science education heavily emphasizes school-based learning and operates under a centralized system. While this approach ensures that all citizens follow the government's prescribed curriculum, it may overlook the voices of certain ethnic groups in the educational content. Many studies in the past have indicated that under a centralized education system, the voices of indigenous peoples and minority groups may be overlooked, leading to a phenomenon of oppression and injustice (Lee, Yen, and Aikenhead, 2012; Li and Shein, 2023; McKinley, 2005; McKinley, Waiti, and Bell, 1992). Additionally, there is a lack of continuing education opportunities for adults after leaving school.

In light of these observations, the following sections will delve into two distinct aspects: Taiwan's public science education initiatives beyond traditional schooling and the efforts to promote equitable science education for disadvantaged groups of learners.

3. Science Education for the Public

Public science education in Taiwan can be categorized into two main implementation directions: hardware facilities and software development. On the hardware front, Taiwan's Ministry of Education has established five national science museums, actively promoting these institutions with the support of the highest educational authority. In terms of software, there is a continuous effort to enhance teacher training and professional development, alongside numerous science outreach programs. Moreover, the National Science and Technology Council, as the highest authority responsible for scientific development in Taiwan, oversees a Department of International Cooperation and Science Education, which is responsible for coordinating various science-related activities.

The following sections will focus on these two aspects, hardware and software, to elaborate on Taiwan's strengths in promoting public science education, as well as the existing inequalities that need to be addressed and improved.

(1) Hardware: Establishment of National Science Museum

Taiwan boasts five national-level science museums, each with unique establishment dates and distinct primary objectives, which bestow upon them diverse functions. As Taiwan is an island nation, two of the museums are dedicated to ocean-related themes, namely marine biology and marine technology. For a comprehensive understanding of each museum, their specific details are provided in Table 1.

Table 1 Science Museums in Taiwan (Sort by establishment time)

Museum	Established	Mission, Goals and Strategies
National Taiwan Science Education Center (NTSEC)	1957	Creating an explorable base of Sciences and Arts in the way of novelty, attraction, fun, interaction and dynamicity.
National Museum of Natural Science (NMNS)	1986	Empower the public with scientific knowledge of nature and culture.
National Science and Technology Museum (NSTM)	1997	Research, design, and display of various technological themes, and to introduce important technological development and its influence on everyday lives.
National Museum of Marine Biology and Aquarium (NMMBA)	2000	Approaches the overall promotion of community, entertainment, international and so forth other than the upgrading of the educational, academic and conservational aspects.
National Museum of Marine Science and Technology (NMMST)	2013	Create an exhibitive, educational, and recreational environment for schools and the public, and supplement our museum with research and archives to encourage the public to “Embrace the Ocean, Appreciate the Ocean and Sustain the Ocean.”

Sources: Official websites of respective museums.

As observed from Table 1, these science museums have a long establishment history, spanning up to 56 years. While the museums boast rich collections, achieving their promotional objectives requires an effort to engage the public. In the past, museums primarily attracted visitors through activities; however, individuals with lower socioeconomic status may not proactively visit museums as it is not deemed a necessity in their daily lives. This has been a significant challenge faced by museums in the past.

As depicted in Figure 1, the museums are predominantly located in the main metropolitan areas and popular tourist destinations of the western half of Taiwan, which offers great convenience for residents in this densely populated region. However, this distribution appears to be unfair for residents in the eastern half, who

face relative deprivation of access to science education resources, leading to a noticeable imbalance in resource distribution.

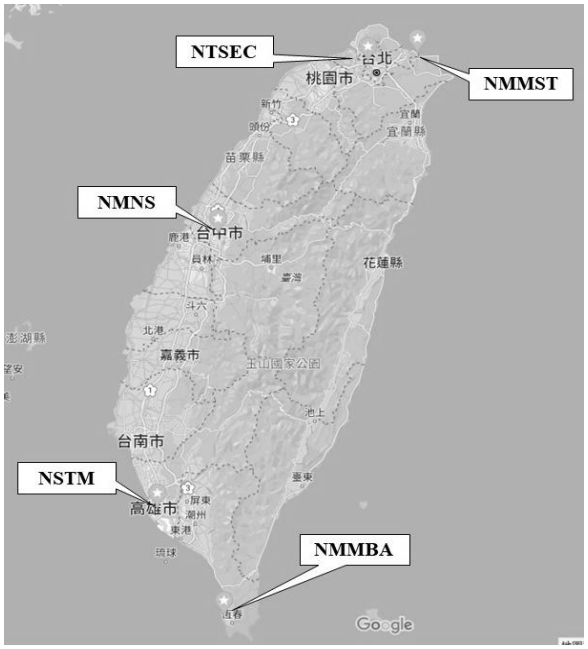

Figure 1　Distribution of national science museums in Taiwan
(Sources: The author compiles the information independently.)

Research conducted by Li and Shein in 2019 further emphasized that science museums serve as crucial centers for science learning in their respective regions, significantly benefiting science education in those areas. However, the government's policy of favoring metropolitan areas when establishing public facilities, including science museums, can exacerbate resource disparities for regions that lack similar resources. This policy direction perpetuates oppression and inequity based on geographical regions, making it even more challenging for deprived areas to access the necessary resources.

In recent years, museums have recognized the importance of leveraging emerging technologies to make their resources more accessible to the public. Utilizing radio, television, and the Internet, physical exhibits in museums have been transformed into virtual interactive software, enabling the public to access these resources without the need to visit the museum in person. This shift indicates the museum's acknowledgment of the disparities and injustices resulting from the urban-rural divide (Lin and Yen, 2012). While the educational outcomes generated by digital education and physical education may differ significantly, they can still significantly reduce the information gap caused by spatial constraints.

However, simply upgrading hardware equipment alone cannot fully address the challenges faced in remote areas. Despite significant investments in hardware equipment in the past, Taiwan has not seen substantial results. Therefore, to be effective, investments in hardware must be complemented by corresponding investments in software. The following paragraphs will explore the various ways science museums invest in software to bridge the gap and ensure equal access to educational resources.

(2) Software: Plan for Popular Science

The previous section discussed Taiwan's establishment of science museums and the challenges they encounter. This chapter aims to explore how museums can promote equalization in public science education through software aspects, specifically by implementing various activities.

Science popularization activities come in various forms, such as interactive science demonstrations directly engaging the public, science delivery services, and projects focused on creative curriculum and teaching material development. Additionally, there are hands-on courses organized specifically for students. While these activities may seem different in form, their core objective remains centered around bringing people closer to science and designing experiences that showcase the practical applications of technology in daily life. The article will focus on explaining three nationally renowned events: the Taiwan Science Festival, Taiwan Railways of Popular Science, and Popular Science Talks.

A. Taiwan Science Festival

To consolidate the resources of the five science museums in Taiwan and promote equitable regional development and access to science, the Ministry of Education initiated the Taiwan Science Festival (TSF) in 2020 (Sun, 2023). The primary objective of TSF is to spark public interest in science by offering engaging and interactive scientific activities. Through funding support, museum resources are extended to reach every town in Taiwan, effectively addressing the issue of inequality caused by geographical distance.

Based on statistics, TSF orchestrates over 1,000 science outreach activities annually. It further ensures equitable access to scientific resources in remote areas (defined as being more than 2 hours' drive from the museum) by deploying mobile vehicles to deliver these resources. This approach facilitates easy access to museum

resources for individuals residing in remote regions, thereby fostering equality in science education.

From the author's perspective, the Taiwan Science Festival (TSF) not only provides abundant and extensive opportunities for science education but also facilitates a collaborative mechanism between schools and museums. This mechanism enables museums to develop instructional materials and activities that better align with school needs, gradually bridging the gap between schools and museums through direct feedback from teachers and students.

B. Taiwan Railways of Popular Science

Taiwan Railways of Popular Science (TRPS) is a national science outreach initiative initiated by Dr. Mei-Hung Chiu in 2016 (Li, 2017). It builds upon the foundation of Popular Science Week, which has been actively promoted since 2015. The program involves renting a train and hosting diverse science education and practical demonstration activities, enabling students to experience firsthand the various scientific phenomena influenced by moving trains. Notably, the initiative goes beyond inviting students from remote areas to participate; it also extends the opportunity to students from outer islands, promoting inclusivity and ensuring wider access to these engaging activities.

TRPS was initially organized by university professors who were responsible for providing science activities for students to experience. However, starting from 2017, high school science clubs were introduced to conduct science demonstrations, which generated a significant response. Many schools began cultivating students with science communication skills, participating in TRPS not only as attendees but also as contributors. This shift can be seen as creating a win-win situation, further expanding the educational significance that TRPS aims to achieve.

C. Popular Science Talks

The two activities, TSF and TRPS, are annual events, each lasting about a week, promoting science and popularization. However, the dissemination of scientific knowledge requires continuous support beyond these events. For this reason, since 2003, Dr. Wang-Long Li has been delivering 16 to 20 scientific lectures annually. These lectures are not only free of charge but are also live streamed online with interactive features. Leveraging the power of the internet, the latest advancements in science can reach every corner of Taiwan, facilitating widespread access to scientific

developments.

From the activities, it is evident that while science museums in Taiwan are predominantly established in metropolitan areas, they are making efforts to address inequality stemming from geographical distance through interactive events and the internet's reach. However, the disparity in science education in Taiwan is not solely attributed to spatial factors; cultural and social elements also play a significant role. Therefore, the subsequent chapters will delve into the current issues of science education in Taiwan arising from cultural and social factors.

4. Improving Science Education Access

(1) Women and Girls in Science Education

For an extended period, women have faced neglect and even exclusion within the scientific community. Consequently, although women's education is quite prevalent, fewer women than men opt to pursue science and engineering majors. Using Taiwan as an illustration, in the realm of natural sciences, women account for approximately 32.3% of the workforce, whereas in engineering, the representation is merely 22.6%. In contrast, in the fields related to humanities and social sciences, the percentage of females is as high as 65.4%. (Statistics Office of the Ministry of Education, 2023). As a response to this disparity, both the National Science and Technology Council and the Ministry of Education have actively invested in programs that foster female scientific talent, aiming to increase the participation of women in the field of science through enhanced support.

Taking the science popularization activities in 2021 as an example, we can observe the inclusion of 10 programs dedicated to cultivating female science and technology talent. Moreover, within the broader scheme of promoting science and technology education, specific policy requirements addressing women's issues in the field of science and technology are also emphasized. These initiatives signify Taiwan's proactive efforts to diminish societal stereotypes that have traditionally portrayed men as the predominant figures in science and engineering.

To achieve such a transformative goal, the school plays a central role. Through education, gender distinctions among subjects are eliminated, and students are actively encouraged to explore beyond conventional boundaries and preconceptions. Providing a supportive and nurturing environment for female students to engage in

scientific exploration enables them to make future career choices based on their own desires, free from the influence of traditional societal norms that once prevailed.

(2) Indigenous Science Education and Place-based Education

Indigenous People possess a profound traditional ecological knowledge (TEK) rooted in their understanding of the environment, ecology, and life. According to Nakashima(1993), TEK refers to the perception and knowledge held by local inhabitants concerning the natural environment. From the viewpoint of Indigenous Peoples, TEK represents the intricate "relationship" between knowledge, individuals, and the encompassing world, as well as the conscientious "process" of actively and responsibly participating in this interconnectedness. The focus lies in fostering relationships and dynamic processes rather than attaining ultimate knowledge (McGregor, 2008).

Once Indigenous students enter formal schooling, they often encounter disparities between the cultural context of the curriculum and their own life experiences, necessitating increased effort and time to engage with their studies. However, if the courses they study in school closely align with their cultural background and even draw from their life experiences, it eliminates the need for extra time and energy and fosters a more seamless connection between students and the curriculum. This approach diverges from the prevailing trend of standardizing and simplifying education in the pursuit of globalization. Instead, it advocates for localized, bottom-up curriculum design. Thus, while striving for globalization, it is crucial to consider the traditional ecological knowledge (TEK) inherent in diverse ethnic groups. Efforts should be made to create synergy between TEK and Western science through mutual resonance, ultimately complementing each other.

Currently, research and initiatives pertaining to Aboriginal science education in Taiwan are thriving, with projects initiated since 2010 focused on advancing studies in Aboriginal culture and education. The objective is to amplify the wisdom and voices of indigenous communities through these projects, thereby redressing the historical oppression and injustice resulting from political interference. Through the concerted efforts of the project group, the aim is to acknowledge and honor the perspectives and knowledge of indigenous peoples, paving the way for a more equitable and inclusive future.

5. Conclusion

Science education plays a pivotal role in a country's overall progress, and it should be accessible to all citizens without any exclusions. However, in the past, science education has not been equally accessible to remote areas, women, and indigenous people due to various cultural, social, and political factors. In the past decade, Taiwan has taken active measures to address these disparities by offering guaranteed placements, providing increased learning opportunities, and developing localized teaching materials. The ultimate goal is to achieve greater equity in science education and ensure that everyone has equal access to science education resources.

Despite these efforts, there is still progress to be made, especially in the era of globalization, where the localization of scientific knowledge can open new avenues for scientific development. In recent years, significant advancements have been made in research concerning Indigenous science education, reflecting an enhanced understanding of the unique local knowledge held by various Indigenous communities. This indigenous knowledge assumes particular significance in the context of the ongoing wave of globalization. By embracing the principles of localization and recognizing the unique knowledge and perspectives of diverse ethnic groups, science education can become more inclusive and responsive to the needs of all individuals, fostering a society where everyone has equal opportunities to engage with and benefit from science education.

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