KOREA 2025

EARCOME9

The 9th ICMI-East Asia Regional Conference on Mathematics Education

Re: Visiting the Essence of Mathematics Education in the Era of Digital Transformation

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Seoul National University, Siheung Campus

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- Topic Study Groups

Co-Host

대한수학교육학회
The Korean Society of Educational Studies in Mathematics

한국수학교육학회
The Korean Society of Mathematical Education

KOREA 2025 수학

EARCOME9

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Welcome Message

It is with great pleasure that we welcome you to the 9th ICMI-East Asia Regional Conference on Mathematics Education (EARCOME 9), held from July 18 to 22, 2025, at Seoul National University's Siheung Campus in South Korea.

EARCOME has become a cornerstone for mathematics education in East Asia, bringing together researchers, educators, and practitioners from across the region and beyond. Its origin can be traced to the South East Asia Conferences on Mathematics Education (SEACME), which began in 1978. Since the first official EARCOME in 1998, the conference has evolved into a triennial gathering—except during ICME years—fostering collaboration, scholarly exchange, and innovation in mathematics education.

The theme for EARCOME 9, "RE: Visiting the Essence of Mathematics Education in the Era of Digital Transformation," invites us to reflect deeply on foundational principles in mathematics education amid the profound shifts driven by digital technology. In this transformative age, questions of purpose, practice, and pedagogy are more urgent than ever.

As the International Program Committee Chair and Co-Chair, we are honored to support a program that reflects the diverse voices and vibrant scholarship across East Asia and beyond. This year's conference is co-hosted by The Korean Society of Educational Studies in Mathematics (KSESM) and The Korean Society of Mathematics Education (KSME). It includes an exceptional lineup of plenary lectures, invited presentations, topic study groups, and practice-oriented sessions for practitioners.

We extend our deepest gratitude to the Local Organizing Committee, co-chaired by Ho Kyoung Ko (Ajou University), GwiSoo Na (Cheongju National University of Education), and Jinho Kim (Daegu National University of Education), whose dedication and leadership have been instrumental in realizing this event. We also acknowledge the many LOC members and volunteers who have contributed their time and expertise to make EARCOME 9 a meaningful and enriching experience.

We are especially grateful for the generous support of the National Research Foundation of Korea (NRF), funded by the Ministry of Education (MOE), under Grant No. NRF-2025S1A8A4A01014320. Their support has been crucial in making this conference possible.

We warmly welcome you to EARCOME 9 and invite you to engage fully in the discussions, share your insights, and help shape a forward-looking, inclusive vision for mathematics education. We hope this conference will not only deepen your academic inquiry but also strengthen our shared commitment to building a collaborative and culturally grounded mathematics education agenda in East Asia.

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The 9th ICMI-East Asia Regional Conference on Mathematics Education

Topic Study Groups 8:

The Essence of Mathematics Education with Equity and Culture

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TSG8-01

FROM TRADITION TO TECHNOLOGY: RETHINKING MATHEMATICS EDUCATION THROUGH ETHNOMATHEMATICS IN INDONESIA

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This research discusses the connection between ethnomathematics and digital transformation in Indonesian mathematics education. Based on a comprehensive literature review of existing studies, we discuss how indigenous mathematical knowledge has been incorporated into dominant teaching practices. The purpose of this study is to analyze trends, challenges, and opportunities in preserving cultural mathematics through the embracement of digital technology. The findings show that there are increasingly more attempts at introducing ethnomathematics into curriculum, although there are still issues with balancing between tradition and technology. The discussion focuses on successful approaches, such as digital storytelling and culturally responsive teaching. Bringing ethnomathematics into the digital era enriches learning experiences while promoting cultural relevance in mathematics teaching.

Keywords: ethnomathematics, digital transformation, Indonesian culture, mathematics education

Introduction

Mathematics is often seen as a universal language, yet its development is shaped by cultural influences. Ethnomathematics examines mathematical ideas within cultural contexts, offering insights into how indigenous knowledge enriches mathematics education. In Indonesia, diverse traditions, including ethnomathematics, influence architecture, textiles, and landscape design (Fuat et al., 2024). As digital education advances, integrating ethnomathematics into teaching can enhance learning and preserve cultural heritage. While technology brings new opportunities, it also presents challenges. Educational technology enables blending local mathematical knowledge with the modern curriculum through apps, virtual environments, and digital storytelling (Nurrahmah et al., 2024; Sunzuma & Umbara, 2025), making math more engaging for students. Integrating ethnomathematics into online learning platforms requires careful examination of teaching methods combined with cultural awareness and sufficient readiness within educational establishments.

Aligning indigenous knowledge with standardized curriculum is a significant obstacle to maintaining cultural mathematics in digital education (Hidayati & Prahmana, 2022). Digital resources for ethnomathematics are limited, highlighting the need for more content and teacher training. However, digital tools like storytelling, AR, and gamification engage students with local concepts (Cirneanu & Moldoveanu, 2024). While AI and big data can uncover patterns in conventional mathematics, confirming its worldwide significance, online platforms encourage collaboration (Soesanto et al., 2022). The intersection of ethnomathematics and digitalization in Indonesian mathematics education is a highly interesting field of research.

As Indonesia attempts to balance preserving its rich mathematical legacy and embracing new technical advances, a thorough procedure for incorporating cultural mathematics into modern education

systems is required. In order to promote more inclusivity and a culturally sensitive mathematics curriculum, this study contributes to the literature by incorporating important findings, challenges, and possible future approaches for integrating ethnomathematics into computerized education systems.

Methodology

This study adopts a systematic literature review (SLR) technique (Boell & Cecez-Kecmanovic, 2015; Greyson, et.al., 2019) to investigate the relationship between ethnomathematics and digital transformation in Indonesian mathematics education. The process comprises a rigorous and intensive review of published scientific literature, including journal articles, conference proceedings, monographs, and policy papers (Murire, 2024). The selection criteria are determined in advance to help establish relevance and reliability.

The study was carried out in stages. Initially, the related literature was identified through a variety of databases like Google Scholar, Scopus, and Web of Science with keywords like "ethnomathematics," "digital transformation," "Indonesian mathematics education," and "culturally responsive teaching." Data extraction and analysis were subsequently carried out via a thematic framework, classifying the results into main themes like digital tools for ethnomathematics, teaching strategies, obstacles to integration, and successful case studies.

The result provides a holistic understanding of how indigenous mathematical knowledge has been incorporated into mainstream education and the role of digital technology in this transformation. The findings give a basis for ongoing discussion of the optimal strategy and possible directions for the inclusion of ethnomathematics in the digital age.

Result and Discussion

The past decade (2015–2025) saw tremendous advancement in ethnomathematics integration and digitalization of Indonesian mathematics education. This section summarizes the findings of the literature review with a focus on trends, challenges, and opportunities in this field.

Trends in Ethnomathematics Integration

Three key points from the trends in ethnomathematics: (1) Growing research interest - Research indicates a growing focus on incorporating ethnomathematics into mainstream education. Hidayati and Prahmana (2022) stress that cultural contexts in mathematics can enhance conceptual understanding and student motivation. Ethnomathematics research in Indonesia has grown exponentially (Iffah et al., 2025), with more universities and institutions recognizing its contribution towards making mathematics education inclusive; (2) Utilization of digital technology - Suzuma and Umbara (2025) work shows digital storytelling has been identified as a particularly effective method of preserving indigenous mathematical knowledge. Triyani, et. al (2012) give an example in teaching Least Common Multiple (LCM) using the storytelling method aloud able to improve students' self-efficacy in learning mathematics. The application of digital technology in ethnomathematics education has gained speed (Irmayanti, et. al., 2025). Digital culture-based media, interactive simulations, and virtual learning environments are being developed to give mathematics education more immersion; (3) Culturally responsive pedagogy - Increasing attention is being placed on culturally responsive teaching styles. Jacob and Dike (2023) state that educators are incorporating pedagogic practices that weave local cultural aspects into math teaching, making the subject more relevant and accessible to students from different backgrounds.

Challenges in Balancing Tradition and Technology

Curriculum standardisation is a significant obstacle to the integration of ethnomathematics into education. It could be challenging to integrate traditional mathematical ideas since they frequently don't fit in with contemporary standardised curricula (Hidayati & Prahmana, 2022). Teacher preparation is another important concern. The quality of education is lowered because many teachers lack the knowledge and tools necessary to safely incorporate ethnomathematics, particularly in online learning contexts (Purwanto et al., 2025). Additionally, there are not many excellent, culturally appropriate digital teaching resources available. This illustrates how urgently education stakeholders must collaborate and boost funding to create relevant content. According to Nurrahmah et al. (2024), not every Commissariat Mathematics Teacher (MGMP) member is familiar with using laptops or computers in the classroom. In order to properly include ethnomathematics in Indonesian education and increase learning's inclusivity and cultural significance, several issues must be resolved.

Opportunities through Digital Evolution

Digital evolution presents significant opportunities for integrating ethnomathematics into education. One promising approach is digital storytelling and gamification, which offer captivating means of introducing mathematical ideas in cultural contexts. Digital storytelling provides a culturally rich learning environment that helps young learners connect with and appreciate mathematics more profoundly (Sunzuma & Umbara, 2025). Gamified elements enhance this experience by making learning interesting and enjoyable. Another important trend that encourages information sharing between indigenous communities, scholars, and educators is the rise of collaborative online platforms. These platforms encourage the collaborative creation of educational materials sensitive to cultural differences and represent a range of customs and beliefs (Putri & Junaedi, 2022). Finally, student involvement has increased dramatically when ethnomathematics is taught utilising digital resources. Such integration increases students' motivation and fortifies their mathematical literacy, making mathematics more significant and applicable to their cultural backgrounds (Maulina et al., 2024).

Conclusion

The intersection of ethnomathematics and digital innovation in mathematics education in Indonesia has both challenges and opportunities. Whereas integrating traditional mathematical knowledge into a homogenized curriculum is problematic, digital technologies hold promise for avenues of preservation and presentation of cultural heritage in education. Furthermore, many teachers lack the necessary skills to incorporate ethnomathematical techniques, emphasizing the need for professional development programs. Besides these challenges, digital transformation offers promising solutions. Educators can use the proper adaptation of such technologies to refine pedagogical practice and promote a greater appreciation of Indonesia's plural mathematical culture. A balance between technology and tradition must be found if ethnomathematics is to be preserved as we forge ahead technologically. Future research and investment in digital educational resources will play a vital role in strengthening the integration of ethnomathematics in Indonesia's evolving educational landscape.

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TSG8-02

INDIGENOUS EPISTEMOLOGY AND ETHNOMATHEMATICS: INSIGHT FROM BHUJEL COMMUNITY

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This study explores the ethnomathematical knowledge and indigenous epistemologies of the Bhujel community renowned for their traditional bamboo crafts. Drawing from participant observations and in-depth interviews with bamboo crafters, this ethnographic research reveals how the Bhujel community's intricate craft practices embody rich mathematical concepts such as measurement, design, and spatial reasoning. The findings of this study revealed that Bhujel indigenous epistemology focuses on individualized instruction and hands-on experiences of the learners to knowledge generation and distribution. This hands-on and informal learning approach helps them to develop essential skills and knowledge to transcend and sustain their lives and preserve their cultural traditions. In the context of bamboo crafts, this approach allows learner to see the practical application of mathematics in real-world tasks. Recognizing these traditional learning methods could help improve educational practices by including and respecting cultural knowledge.

Keywords: Culture, Ethnomathematics, Indigenous epistemology, Mathematical knowledge

Introduction

The Bhujel community is one of the indigenous ethnic groups in Nepal. They have their own language and rich cultural heritage that reflect their unique identity and way of life. The Bhujel has the traditional job of constructing bamboo crafts. The mathematical ideas and procedures elaborated in the construction of bamboo crafts and studying the ethnomathematics in the Bhujel community provide valuable insights into how ethnomathematics is embedded in cultural practices and traditions. Thus, ethnomathematics is the mathematics practiced by different cultural groups, such as groups of workers, professional classes, children in a certain age group, indigenous societies, and many other groups identified by their common objectives and traditions (D'Ambrosio, 2006). Further, Rosa and Orey (2016) state that ethnomathematics refers to the mathematical ideas and concepts embedded within diverse cultural contexts. Thus, ethnomathematics highlights the importance of recognizing and valuing diverse forms of mathematical knowledge systems and the ways of knowing and doing of different groups of indigenous cultures.

The Bhujel community has been engaged in the mathematical activities of counting, measuring, designing, playing, locating, and explaining in their daily lives. The way that bamboo craftsmen acquire and apply mathematical knowledge in their everyday activities, the study provides valuable insights into the ways of knowing and doing of their own mathematical knowledge and skills. The main objective of this study was to explore the ethnomathematical ideas, knowledge, and indigenous epistemology of the Bhujel community. The mathematical concepts and skills applied in a different cultural context of the Bhujel promote greater understanding and appreciation of diverse cultural practices and knowledge systems.

Methods and Procedures

In this research, I used qualitative research methods as I wanted to make sense of the complex world of the implicit mathematical knowledge of the Bhujel and their ways of teaching and learning i.e., epistemologies (Pradhan, 2023) of Bhujel people. In particular paradigm, I adopted ethnographic methodology to obtain research objectives. The Bhujels of Adhimul of Bandipur Rural Municipality of Tanahun District have recognition of the construction of different bamboo-related pieces of stuffs and where there are substantial numbers of Bhujels carrying on this ages-long occupation. I selected total of six including four of bamboo crafts workers and two school-going children who participated in their household activities purposively as my research participants.

I used in-depth interviews which are mostly known as open-ended interviews or ethnographic interviews with the help of interview guidelines so that it is easier for me to generate the data in the fields. In the same, I used participant observation and non-participant observation to generate the data to support my study. I carefully recorded all the possible conservations with the help of the video camera and took field notes as much as I could with the consent permission of my research participants. Though I had made a schedule for data gathering, it was largely ineffective as I had to work as per the wishes of my research participants. I followed them wherever possible. I even traced their children's schools, visited them, talked to the headmaster, and teachers, and gathered information about their children's achievements in the academic field. After finishing the collection of the data, I converted the conversations and interviews into manuscripts so that I could easily analyze and interpret them. The main task of the research is to analyze and interpret the data collected from the field. I adopted Braun and Clarke (2006) process of data analysis and interpretation. They developed a six-phase thematic analysis method which includes familiarizing the data with reading and re-reading, generating initial codes systematically across the dataset, searching for themes by grouping similar codes, reviewing themes to refine and ensure they represent the data accurately, defining and naming themes to capture the essence of each, and drawing findings relation to research questions.

Bhujels' Epistemologies and Ethnomathematics

Knowledge is generated in formal and informal ways. Most of the educational institutions follow the western approaches to generate and transform knowledge. However, there are many indigenous epistemologies to knowledge generation and transformation in the world. It is apparent that people from different ethnic communities and cultures do have their own specific ways to produce knowledge. Most of the indigenous knowledge generation approaches share the common phenomena despite the different geographical variations and different cultural patterns. The Bhujel indigenous community of Nepal has a traditional system of learning that is deeply rooted in their culture and way of life. In this study, a total of six participants from the Bhujel community including two young school children were included. I interviewed with research participants about the indigenous epistemologies on how the Bhujel people generate and distribute knowledge to crafts bamboo artifacts and observed ethnomathematical ideas and knowledge practiced in the process of constructing bamboo artifacts. There are many ways to learn. People can learn from their cultural and environmental surroundings in variety of ways. One of them is apprenticeship which is characterized by a hands-on approach to learning (Fjellstrom & Kristmansson, 2019). With this regard, I asked Saila Bhujel (42) about how he learnt skills and knowledge of bamboo crafts. Saila shares his experience as

> *I learnt bamboo crafts with my elder brother. He encouraged me to do with him and told me: "If we learn and adopt our ancestral job, we can survive even in the famine situations. If we have skills, it saves us in any difficult and unfavorable situations". Then I motivated to work with him. I involve in this job for more than two decades.*

From the interview with Saila Bhujel, they have a long-standing tradition of bamboo weaving, which has been passed down from generation to generation through a system of apprenticeship. The apprenticeship system starts at a young age, with children learning from their parents or other elders in the community. The mentor will often take on one or two apprentices at a time, and work with them closely to develop their skills and knowledge. Regarding the knowledge generation approach within the Bhujel community, I asked another participant Saroj (21):

> *I learnt Nanglo weaving with my father. My father encouraged me to work with him. My mother also involves in the bamboo crafts process. We have to brought bamboo from other people and work together to processing bamboo, and preparing materials for weaving. I closely observed my father about the process to construct Nanglo crafts. After some time, I became a perfect crafter.*

From the interview with Saroj, It comes to be known that the apprenticeship system is characterized by a hands-on approach to learning. Apprentices are given practical tasks to complete, such as harvesting and processing bamboo, preparing materials for weaving, and weaving simple structures. This type of learning allows apprentices to develop their skills and knowledge through observation, practice, and feedback (Fjellstrom & Kristmansson, 2019). In my observation, I found that there is no formal class managed for sharing the knowledge of the Bhujels. However, the knowledge has been transformed from one generation to the next generation since long. Much of the knowledge about bamboo crafts in the Bhujel community is passed down through informal learning methods, such as observation, participation, and apprenticeships. This type of learning is often experiential and hands-on, allowing for the transmission of practical knowledge from one generation to the next. The Bhujel community places a high value on the inter-generational transmission of knowledge, with elders passing on their expertise to younger members of the community.

Indigenous peoples have their own ways of teaching and learning approaches. Indigenous people use a variety of sophisticated mathematical ideas and concepts in their everyday work (D'Ambrosio, 2006; Rosa and Orey, 2016). The Bhujels have made wonderful bamboo crafts involving a high level of knowledge and skill. I observed the bamboo craftsmen's workplace and found lots of mathematical concepts in the bamboo artifacts. I interviewed Ram Bhujel (38 Years) regarding the process of the construction of the artifacts. Ram speaks:

> *I used to construct Nanglo (flat round woven tray) and divide the large bamboo bar into pieces about the length of two haat (cubit). Then split it into two parts and each part into two halves to make each piece about an amal (digit). The number of separations is based on the motai (diameter) of the bamboo bars.*

Nanglo is a flat round woven tray made up of bamboo. It is made traditionally out of thin bamboo pieces intermingled into a flat surface. It is used to winnow rice, paddy, beans, grains, and other foodstuffs. It can be seen that it resembles a perfect circular shape. The Bhujel community uses various measurement systems, such as body parts, bamboo nodes, and finger spacing to measure the length, width, and thickness of bamboo, which is a common practice in many indigenous communities. The geometric concepts such as angles, triangles, various polygons, and circles are found in their bamboo crafts. From the interview with Ram, it comes to know that the Bhujels use

mathematical concepts in various ways during the cutting of bamboo strips, and dividing strips into equal parts during the construction process. There is a specific application of the concept of fractions, particularly in the context of partitioning bamboo logs into equal pieces. In this context, the implicit use of fractions is a practical and hands-on application of mathematical concepts within the traditional craftsmanship of the Bhujel community. This implicit use of fractions reflects the community's knowledge and skills in working with bamboo as a material for crafting. These strategies are historically organized in indigenous culture as knowledge systems (Sharma and Orey, 2017). Concerning the production of different crafts, I asked Ram Bhujel about the types of bamboo crafts they like to produce. He shared his view:

> *We construct bamboo craft according to the demand of the market. In my workplace, Nanglo, Chalno, Doko, and Thumse are the main productions. Now we are preparing Nanglo, it has higher demand than others. The construction of Nanglo can be collaborative work. The flat surface of Nanglo can be crafted by female workers and younger school children. Wages for the construction of Nanglo are comparatively cheaper than the others*.

From the observation in my field study and the interviews with my research participants, it is found that the ethnomathematical knowledge of bamboo crafts in the Bhujel community highlights the intricate and sophisticated mathematical knowledge and practices embedded in traditional crafts. The above narrative reflects key mathematical concepts such as optimization, labor cost, and resource allocation. The decision to prioritize the production of *Nanglo* is based on higher market demand and lower labor costs illustrated an optimization strategy to maximize profit with allocation of limited resources. Thus, the ethnomathematics recognizes the inherent mathematical concepts underlying these practices, such as proportional allocation of labor and optimization of production processes. From the indigenous knowledge and epistemological perspective, ethnomathematics focuses on the ways, the styles, the arts, the techniques, generated by Bhujel people to explain, understand, and cope with their environment, particularly in the construction of bamboo-based artifacts (D' Ambrosio 2006; Pradhan, 2023). Their indigenous epistemologies can be linked with the formal mathematics lesson by designing hands-on activities to explore geometrical and optimization concepts. These concepts can be contextualized through real-life examples from students' cultural backgrounds. The Bhujel people have their distinctive methods of comparing, classifying, quantifying, measuring, explaining, generalizing, inferring, and, evaluating the phenomena in the course of the construction of various bamboo stuffs. Recognizing such indigenous knowledge and practices enriches the formal mathematics curriculum by making it more inclusive and contextually relevant. Integrating indigenous epistemology supports diverse ways of knowing and helps students connect classroom learning to their cultural experiences.

Concluding Remarks

The Bhujel indigenous community of Nepal has a rich traditional system regarding knowledge generation and distribution. The knowledge is handed down from generation to the next generation through observation, imitation, and practical experience. The community places a high value on experiential learning where learners are given hands-on experience and opportunities to practice their skills. Their practices involve sophisticated use of fractions, measurements, geometry, symmetry, and patterns, highlighting implicit mathematical skills embedded in weaving bamboo crafts and everyday activities. It can be concluded that the intergenerational, collaborative and community participation enhanced the knowledge generation and distribution of the Bhujels community. Recognizing and valuing Bhujel's epistemologies and their ethnomathematical knowledge can contribute to a more inclusive and culturally relevant mathematics education.

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TSG8-03

A STUDY ON MATHEMATICAL CURRICULUM IN AN INDIGENOUS SCHOOL IN TAIWAN: FOCUSING ON THE PROCESS OF CURRICULUM DESIGN

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This study explores the integration of Indigenous knowledge into the mathematics curriculum at an Indigenous school in Taiwan, using Alan Bishop's (1988) five principles—representativeness, formality, accessibility, explanatory power, and broad scope—as an analytical lens. The school employs a culturally responsive approach, incorporating ecological knowledge and mathematical concepts to enhance both cultural relevance and academic rigor. Through field-based learning, storytelling, and bilingual instruction (Mandarin and the Indigenous language), the curriculum fosters meaningful engagement. By connecting mathematics with themes such as climate change, ecology, and architecture, the program encourages interdisciplinary learning. Findings suggest that embedding indigenous knowledge in mathematics education strengthens cultural identity, increases student engagement, and improves academic performance, offering a model for developing culturally responsive Indigenous curricula.

Keywords: Indigenous Knowledge, Mathematics Education, Culturally Responsive Pedagogy, Academic Performance, Cultural Identity

Introduction

Mathematics has often been viewed as a universal discipline, independent of cultural influences. However, Bishop (1988) challenged this notion, arguing that mathematics is fundamentally a cultural construct shaped by societal needs, values, and practices. Activities such as counting, measuring, and designing are deeply embedded in different cultural traditions, reflecting unique ways of understanding and interacting with the world. However, mainstream mathematics curricula frequently disregard indigenous knowledge systems, which include advanced mathematical practices such as navigation, land measurement, and geometric design. This disconnect not only hinders indigenous students' academic performance but also fosters a sense of alienation in the classroom (D' Ambrosio, 1985; Harris, 1980).

Mathematical enculturation (Bishop, 1988) offers a way to bridge this gap by embedding cultural elements into mathematics education, making learning more relevant to students' experiences. By

integrating traditional knowledge into lessons, students can connect mathematical concepts to their daily lives and cultural heritage. This study examines the development of a mathematics curriculum in an indigenous school in Taiwan, focusing on the process of incorporating cultural perspectives into teaching. Drawing on the frameworks of ethnomathematics and culturally responsive pedagogy, this study examines how culturally embedded mathematics education can enhance student engagement, address learning disparities, and support the development of academically rigorous curricula. By situating mathematical instruction within students' cultural contexts, such approaches contribute to advancing educational equity in Taiwan.

Literature Review

Mathematics is not universal but deeply rooted in cultural practices, shaped by societal needs and values (Bishop, 1988). Activities like counting, measuring, and designing vary across cultures, reflecting unique ways of thinking. Mathematical enculturation emphasizes embedding cultural practices into education to make mathematics meaningful and relevant to students from culturally and linguistically diverse backgrounds. For indigenous students, this approach bridges abstract concepts with their lived experiences, fostering both academic success and cultural pride (D'Ambrosio, 1985). By integrating traditional activities such as hunting and weaving, enculturation validates cultural heritage while enhancing mathematical understanding.

Alan Bishop (1988) identified five principles for creating culturally embedded curricula: representativeness, formalization, accessibility, explanatory power and broad scope. Representativeness refers to incorporating significant cultural practices, such as adopting traditional land measurement to make mathematics relatable. Formalization refers to transforming cultural practices into abstract mathematical representations; for example, algebraic patterns derived from oral traditions. Accessibility refers to ensuring content aligning with students' cognitive and linguistic abilities by using tools like traditional counting methods. Explanatory power refers to demonstrating the connection between cultural practices and mathematical concepts, such as symmetry in traditional art. Broad scope refers to covering multiple mathematical domains while building a strong foundational understanding. These principles guide the development of curricula that are both culturally meaningful and academically rigorous, meeting the unique needs of indigenous students.

Methodology

Grounded in Alan Bishop's (1988) concept of mathematical enculturation and D'Ambrosio's (1985) ethnomathematics emphasizing the integration of indigenous cultural practices into mathematics content, this study adopted the case study approach, involving iterative cycles of planning, observation, and reflection. Such an approach aligns with the goal of collaboratively designing and refining a culturally embedded mathematics curriculum while addressing real-world challenges.

Padan Asang School, an indigenous experimental education institution located in southern Taiwan, was selected as the research site due to its distinctive approach to curriculum design, which integrates Bunun culture into disciplinary studies. Currently, the school serves students from pre-kindergarten through ninth grade. Beginning in August 2026, it will become the first and only indigenous experimental education school in Taiwan to offer a continuous program from pre-kindergarten through twelfth grade. As a pioneering institution in the preservation of Bunun culture, the cultivation of Bunun talent, and the incorporation of indigenous knowledge and wisdom into formal education, Padan Asang School provides a valuable model. Investigating its curriculum, as well as

its teaching and learning materials, offers critical insights into how such culturally grounded educational frameworks may be adapted to support other indigenous experimental education schools that represent diverse cultural contexts.

The research process consisted of four steps, including identifying cultural and educational needs through consultations with stakeholders, designing culturally relevant mathematical activities, piloting the activities in classrooms and gathering feedback, and refining the curriculum based on observations and evaluations. Three groups of participants consisted of school principal, mathematics teachers and community members. Community members includes local elders and cultural experts who can provide insights into traditional practices and knowledge systems. All participants were selected through purposive sampling to ensure their direct involvement in the curriculum development process. That is, teachers contributed to curriculum design and implementation, while elders offered guidance on cultural relevance; the school principal is the leader and facilitator to oversee the overall process.

Qualitative data is collected for this study. Semi-structured interviews were conducted with teachers and community members to gather insights on cultural practices and educational needs, such as identifying relevant indigenous knowledge systems and their applicability to mathematics. Focus group discussions were conducted with participants to gather their perceptions of the culturally embedded curriculum, focusing on its relevance and impact on their teaching. Interviews and focus group discussion were transcribed by verbatim and then analyzed thematically to identify recurring themes to gain insights.

Results and Conclusion

Alan Bishop (1988) proposed five key principles for curriculum development: representativeness, formality, accessibility, explanatory power, and broad and elementary scope. These principles provide a framework for developing culturally embedded mathematics curricula, ensuring that indigenous students can connect mathematical concepts with their lived experiences. Results of the analysis of the indigenous experimental school-based mathematics curriculum development plan are presented below.

Firstly, Bishop emphasized that mathematics curricula should incorporate culturally significant mathematical practices (Bishop, 1988). The indigenous curriculum strongly aligns with this principle by embedding traditional ecological knowledge into the learning process. The curriculum integrates indigenous environmental knowledge by incorporating land measurement, astronomical observations, and environmental sustainability into mathematical learning. The curriculum actively involves indigenous elders and cultural experts, ensuring that mathematical concepts are taught within a culturally relevant and authentic learning environment, reinforcing students' cultural identity while acquiring mathematical skills.

Secondly, the indigenous experimental school curriculum effectively formalizes cultural practices into academic mathematics instruction through a structured approach. The curriculum translated the oral tradition and indigenous knowledge into structured mathematical instruction which ensures that students move from experiential learning to abstract mathematical reasoning, formalizing indigenous concepts into measurable and testable academic knowledge. The curriculum connects indigenous knowledge with natural sciences and mathematics, making formal mathematical skills—such as geometry, statistics, and algebra—integral to environmental and cultural studies.

Thirdly, accessibility ensures that students can understand and engage with mathematical content based on their cognitive development and cultural familiarity (Bishop, 1988). The indigenous experimental school curriculum incorporates several strategies to make mathematical concepts more accessible and understandable to indigenous students. The designed activities include hands-on learning in real-world contexts, cultural storytelling as a pedagogical tool, and use of indigenous language in mathematical instruction. By prioritizing experiential, community-based, and linguistically inclusive approaches, the curriculum ensures that students engage with mathematics in a way that aligns with their learning styles and lived experiences.

Fourthly, the indigenous experimental school curriculum excels in the aspect of explanatory power by illustrating the practical mathematical significance of indigenous traditions. The curriculum explores the importance of understanding geometric principles in indigenous house building process, which students learn about triangular stability, load distribution, and spatial symmetry, integrating engineering concepts into cultural practices. By demonstrating how indigenous knowledge inherently involves mathematical reasoning, the curriculum helps students see the broader relevance of mathematical skills in their cultural contexts.

Finally, a strong curriculum should provide a broad foundation across multiple mathematical domains, preparing students for future learning while remaining culturally relevant (Bishop, 1988). The indigenous curriculum achieves this through a well-balanced structure that covers diverse mathematical areas. The curriculum integrates arithmetic, geometry, algebra and statistics. The curriculum not only preserves indigenous knowledge but also connects it to modern applications, ensuring that students gain transferable mathematical skills applicable in contemporary fields such as environmental science, engineering, and data analysis.

An illustrative example of applying the aforementioned five principles is a lesson centered on the construction of traditional bamboo houses. According to a school director, the Bunun people historically built and lived in bamboo houses, utilizing locally available natural resources. Through their unique skills and deep understanding of bamboo's properties, the Bunun were able to construct dwellings resilient to strong winds and heavy rainfall, while maintaining stable indoor temperatures in both cold and hot weather conditions.

To provide students with an experiential understanding of how their ancestors lived in harmony with nature, the school developed a curriculum project around this traditional practice. The mathematics lesson began with students conducting interviews with Bunun elders to learn about the historical and cultural significance of bamboo houses, including the reasons behind their construction, the types and parts of bamboo used for different structural elements, construction techniques, and associated cultural taboos. Drawing on this body of indigenous knowledge and cultural wisdom, students and teachers collaboratively applied mathematical concepts to build their own bamboo houses. The process involved tasks such as measuring bamboo lengths, cutting bamboo into appropriate sizes for walls, pillars, and roofs, and applying mathematical principles—such as the Pythagorean theorem and trigonometry—to ensure the structural stability of the construction.

Through this hands-on project, students engaged in a meaningful integration of cultural heritage and academic knowledge. Beyond reconstructing a traditional Bunun dwelling, the experience facilitated a process of cultural rediscovery and identity formation, empowering students to connect their indigenous heritage with contemporary learning and modern perspectives.The indigenous curriculum development should align closely with Alan Bishop's five principles, successfully embedding cultural knowledge into mathematical education while ensuring academic rigor. Hands-

on, experiential learning methods would make abstract concepts easier to grasp. Well-structured approach could translate cultural practices into formal mathematical instruction. Clear demonstration of mathematical reasoning in cultural traditions will foster students' deeper understanding. By adhering to these principles, the curriculum serves as a model for integrating indigenous knowledge into mathematics education, offering valuable insights for developing more culturally responsive curriculum in the future. It is hoped that such culturally responsive curricula create accessible and meaningful learning contexts that actively engage indigenous students, enabling them to acquire and master academic content and skills. Through this culturally grounded foundation, students are better positioned to transfer their knowledge and competencies across disciplinary boundaries, thereby enhancing their overall academic confidence and achievement. In this way, culturally responsive education serves as a more equitable and inclusive approach, addressing the specific needs and strengths of indigenous learners.

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TSG8-04

MATHEMATICS ANXIETY ACROSS ETHNIC COMMUNITIES IN NEPAL

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Mathematics anxiety is a significant barrier to academic achievement for the students from diverse ethnic backgrounds. This study investigated mathematics anxiety among various cultural groups in secondary schools in Nepal. The research employed a cross-sectional survey approach, using the Revised Mathematics Anxiety Rating Scale (RMARS) to evaluate 625 ninth-grade students from 12 randomly chosen schools in Kathmandu. The participants included students from diverse cultural backgrounds (Brahmin/Chhetri, Newar, Mongolian, Scheduled Caste, and Others). Results indicated notable differences in mathematics anxiety levels among cultural groups, with Scheduled Caste students facing the highest anxiety levels, whereas Brahmin/Chhetri students exhibited the lowest. The results highlight the necessity of creating culturally responsive teaching strategies and applying focused interventions to support marginalized populations in mathematics education.

Keywords: Cultural Diversity, Culturally Responsive Pedagogy, Mathematics Anxiety

Introduction

Mathematics anxiety (MA) is an essential psychological phenomenon to researchers, educators, and psychologists (Belbase et al., 2024; Wang et al., 2020). Previously, Dreger and Aiken (1957) introduced the concept of MA as "number anxiety" and a feeling of pressure and fear that impede the use of numbers and mathematical operations in both academic and in real-life situations (Richardson & Suinn, 1972). Several studies have attributed MA to many causal factors such as poor test result, age, negative classroom experience, lack of eagerness to complete a difficult assignment, negative attitude towards mathematics learning, and gender (Dowker et al., 2016; Paudel, 2019; 2023).

Mathematical concepts emerging from the culture of individuals, the recognition of their methods of knowledge creation and sharing, along with students' experiences, ought to be integrated with formal mathematics in educational settings (Pradhan, 2017). Most of the researchers have been reported conflicting findings on gender differences in mathematics anxiety (Dowker et al., 2016). However, mathematics learning appears to be shaped by students' cultural backgrounds and their ability relate mathematical concepts to everyday life experiences. Therefore, mathematics education should empower students to apply mathematical operations within their own cultural context (Pradhan, 2017). Mathematics anxiety has been an issue in research because of the negative impact of MA on an individual's initial and future learning, achievements, and use of mathematics (Dowker et al., 2016; Soumen & Susanta, 2018). However, MA has often received less attention over the years (Foley et al., 2017), and the role of gender within and among cultures remains less explored globally (Morsanyi et al., 2016) and locally (Belbase et al., 2024). In this context, this study was intended to explore the differences of mathematics anxiety across various cultural groups (*Brahmin/*

Chhetri, Newar, Mongolian, scheduled caste, and Others) among secondary students of Nepal. This research was guided by research question: are there significant differences in mathematics anxiety levels among various cultural groups of secondary students in Nepal?

Method

This quantitative research employed a cross-sectional survey design to explore mathematics anxiety across various cultural groups among 9th-grade students in Kathmandu, Nepal. The research employed random cluster sampling to choose 625 students from 12 randomly chosen secondary schools in Kathmandu. The sample consisted (Brahmin/Chhetri 311, Newar146, Mongolian 59, scheduled caste 19, and Others 90) students. The study adopted the Revised Mathematics Anxiety Rating Scale (RMARS) (Plake & Parker, 1982), consisting of 24 items rated on a 5-point Likert scale (1 = No anxiety to 5 = Extremely high anxiety). Moreover, it consisted learning mathematics anxiety (16 items) and evaluation mathematics anxiety (8 items). In the context of Nepal, Paudel (2023) established the instrument's reliability by Cronbach's alpha coefficient, which was 0.84, and validated its content through expert evaluation. The process of data collection involved obtaining the essential approvals from school authorities and distributing surveys during regular school hours, ensuring that participation was voluntary and responses remained confidential.

The gathered data underwent thorough statistical analysis employing both descriptive as well as inferential statistical methods. Descriptive statistics involved computing mean scores and standard deviations for every cultural groups. Inferential statistics included one-way ANOVA to examine disparities among cultural groups, and Tukey HSD post-hoc analysis for various comparisons. All statistical analyses were performed with Statistical Package for the Social Sciences (SPSS) to guarantee precise and dependable outcomes in exploring the connections between cultural background and mathematics anxiety among secondary school students.

Findings and Discussion

Table 1 indicates the mathematics anxiety among secondary students in different cultural groups

Table 1. Descriptive statistics of math anxiety scores among cultural groups in secondary students

Cultural Groups	N	Mean	Std. Deviation	Minimum	Maximum
Brahmin and Chhetris	311	47.3280	13.94928	30.00	92.00
Newar	146	60.7397	11.26487	43.00	94.00
Mongolians	59	60.6441	25.63387	34.00	97.00
Scheduled Caste	19	75.9474	14.10072	53.00	97.00
Others	90	52.1111	8.70805	38.00	71.00
Total	625	53.2768	15.98212	30.00	97.00

The study results show notable differences in mathematics anxiety among various cultural groups in secondary students, with an overall sample size of 625 individuals. The examination reveals that Scheduled Caste students faced the greatest levels of anxiety (M = 75.95, SD = 14.10), with Newar students next (M = 60.74, SD = 11.26) and Mongolian students following (M = 60.64, SD = 25.63).

In comparison, Brahmin and Chhetris, comprising the largest group (n = 311), exhibited significantly lower anxiety levels (M = 47.33, SD = 13.95), whereas the "Others" group (n = 90) presented moderate anxiety levels (M = 52.11, SD = 8.71).

Table 2. One-way analysis of variance (ANOVA) findings for math anxiety among cultural groups

	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	32227.096	4	8056.774	39.283	.000
Within Groups	127160.018	620	205.097		
Total	159387.114	624			

The ANOVA findings validated meaningful statistical differences among these cultural groups $F(4,620) = 39.283$, $p < .001$, suggesting that the noted disparities in mathematics anxiety are closely linked to cultural background. The significant difference in anxiety levels, especially the higher scores of Scheduled Caste students in relation to Brahmin and Chhetris, underscores possible issues of educational equity. The results indicate a necessity for focused strategies that take cultural elements into account when tackling mathematics anxiety, particularly for marginalized populations experiencing elevated levels of mathematics related stress.

The Tukey HSD post-hoc analysis showed notable pairwise differences in mathematics anxiety across various cultural groups ($p < .05$). Students from Scheduled Castes exhibited notably elevated anxiety levels in comparison to other groups, with the greatest mean difference identified between Scheduled Castes and Brahmin/Chhetris (MD = 28.62, $p < .001$). Newar and Mongolian students exhibited comparable levels of anxiety (MD = 0.10, $p = 1.000$), however, both groups had notably greater anxiety than Brahmin/Chhetris (MD = 13.41 and 13.32 respectively, $p < .001$). The "Others" group exhibited moderately increased anxiety compared to Brahmin/Chhetris (MD = 4.78, $p = .043$) but significantly less anxiety than Newar (MD = -8.63, $p < .001$), Mongolian (MD = -8.53, $p = .004$), and Scheduled Caste students (MD = -23.84, $p < .001$). These results statistically validate the hierarchical structure of mathematics anxiety among different cultural groups, with Scheduled Caste students facing the highest level of anxiety and Brahmin/Chhetri students facing the lowest. This clear difference is especially apparent when juxtaposed with Brahmin and Chhetri students, who displayed significantly reduced anxiety levels (M = 47.33, SD = 13.95). The ANOVA results alongside the subsequent Tukey HSD post-hoc analyses, affirm the statistical significance of these differences, indicating that cultural background significantly influences students' mathematical anxiety, which aligns with Pradhan's (2017) claim regarding the necessity of incorporating cultural contexts into mathematics education. The significant anxiety disparity between marginalized populations and historically privileged groups highlights more profound systemic problems in mathematics education, backing the worries expressed by researchers regarding the importance of focusing on cultural elements of MA (Foley et al., 2017; Morsanyi et al., 2016), and indicating the need for culturally responsive strategies to foster educational equity (Belbase et al., 2024; Pradhan, 2017).

After the quantitative analysis of the data, the researchers talked to two 'more anxious students of the scheduled caste until the data were saturated. The researchers collected more than 50 narratives among which the two have been presented here as testimonials:

> "There are nine members on my family live in three-room house, most of the seniors are not well educated and they do not give values for education, I could not get a peaceful place to read at my home". (*Raj, a IX grade student*)

> "I could not get support at school from my subject teacher and friends on solving mathematical problems. Teacher only prioritizes the brilliant students in class, never asks if I understand the mathematical concepts, teacher barely allows sharing my difficulties and provides feedback; and due to economic condition, my family hardly provides extra support at home for my study". (*Sanu, a IX grade student*)

These representative narratives indicated that the students were unable to get the suitable home environments: physical, economic, and psychological; sufficient support at schools from their teachers and peers; and at home from their parents and seniors. In a nutshell, the three themes: the unfavorable home environment, weak student support system and socioeconomic condition were the major causes for mathematics anxiety. The analysis of the data highlighted the influence of ethnic background of students on mathematics anxiety levels and the need for culturally responsive pedagogies to promote educational equity.

Conclusion and Implications

The research reveals significant differences in mathematics anxiety amongst cultural groups in Nepal's secondary education, with Scheduled Caste students experiencing the highest level of anxiety, in contrast to Brahmin and Chhetri students, who displayed the lowest anxiety. These results emphasize the need for specific educational strategies that take into account cultural backgrounds. Educators and policymakers need to create teaching methods that are culturally responsive, with a particular emphasis on assisting marginalized groups such as Scheduled Caste students. Professional development initiatives ought to improve educators' cultural awareness and understanding of how diverse backgrounds affect mathematics anxiety. The education system must establish regular monitoring of anxiety levels among different demographic groups and initiate systemic reforms to foster more inclusive learning environments, ensuring educational equity for every student regardless of their cultural background.

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TSG8-05

A STUDY ON MATHEMATICS CURRICULUM AT AN INDIGENIOUS SCHOOL IN TAIWAN: FOCUSING ON THE PRODUCTION OF MATHEMATICAL TASK

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This study explored the development of a mathematics curriculum in an indigenous school in Taiwan, focusing on the design and implementation of mathematical tasks. Grounded in Bishop's (1988) framework of mathematical enculturation, the curriculum incorporates symbolic components (mathematical concepts), social components (mathematics in societal applications), and cultural components (the value of mathematics within culture), this study collect data through field observations and classroom practices to understand the process of developing mathematical tasks rooted in indigenous life experiences. Results indicated that integrating mathematics learning with cultural practices significantly enhances students' engagement and academic performance while strengthening their cultural identity. This study provides empirical insights and a reference for future indigenous mathematics curriculum development.

Keywords: Indigenous Knowledge, Mathematics Education, Culturally Responsive Pedagogy, Mathematical tasks

Introduction

Mathematical concepts are often perceived as universal, but Bishop (1988) argued that it is shaped by cultural and societal needs. Different communities develop mathematical knowledge in unique ways. In Taiwan, indigenous groups also possess rich mathematical traditions, including the Bunun people's astronomical calculations, the Amis people's geometric patterns, and the Paiwan people's architectural structures. However, the current curriculum follows Western frameworks, rarely incorporating indigenous knowledge, creating cognitive barriers for students (Harris, 1980).

Ethnomathematics emphasizes mathematical diversity and promotes culturally responsive education (D'Ambrosio, 1985). Bishop (1988) expanded this through mathematical enculturation, which integrates symbolic (mathematical representations), social (societal applications), and cultural (identity-based) components into learning. This study applies Bishop's (1988) framework to develop a mathematics curriculum at an indigenous school in Taiwan, focusing on task design and implementation. By integrating indigenous cultural knowledge, the curriculum seeks to enhance student engagement, mathematical comprehension, and cultural identity. This research also offers insights

into curriculum reform, promoting a more culturally responsive approach to indigenous mathematics education.

Literature Review

Mathematics is not an independent body of knowledge but a product of human societies, shaped by cultural practices and needs (Bishop, 1988). Different cultures develop unique mathematical methods. Integrating cultural contexts into mathematics learning can enhance students' understanding and motivation. However, conventional curricula often rely on Western frameworks, neglecting cultural variations in mathematical thinking, which may result in indigenous students' lag-behind learning. Addressing this gap by incorporating culturally relevant mathematical experiences is crucial for improving indigenous students' learning engagement and learning outcomes, which serves to be promoting a more equitable educational approach in Taiwan.

Ethnomathematics highlights the diversity of mathematical thoughts, advocating for integrating local knowledge systems into education to enhance learning (D'Ambrosio, 1985). For example, Taiwan's indigenous groups possess rich mathematical traditions, such as the Bunun people's astronomical calculations, the Amis people's geometric patterns, and the Paiwan people's architectural proportions. However, traditional mathematics education rarely incorporates these cultural elements, making it difficult for indigenous students to connect mathematics to their experiences. By embedding ethnomathematical principles into curricula, this study aims to bridge that gap, fostering both mathematical competence and cultural identity.

Mathematical tasks play a crucial role in curriculum development and should consider students' cognitive abilities, social interactions, and cultural backgrounds (Stein et al., 1996). Well-designed tasks encourage reasoning, problem-solving and mathematical thinking (Henningsen & Stein, 1997). In cultural contexts, tasks should reflect real-life experiences, such as agricultural calculations, hunting area measurements, and traditional architecture design, making learning more meaningful. Research shows that when students engage with mathematics in familiar cultural settings, their motivation and performance improve significantly (Nasir & Hand, 2008). Thus, designing culturally embedded mathematical tasks is essential for enhancing indigenous students' learning experiences.

Bishop (1988) introduced mathematical enculturation, emphasizing that mathematics education should occur within cultural contexts to help students relate mathematical concepts to their heritage. His framework consists of three components: symbolic, social, and cultural.. The symbolic component refers to mathematical representations such as numerical systems, measurement units, and geometric patterns. The social component focuses on how mathematics is applied in economic transactions, architectural planning, and agricultural management. The cultural component examines mathematics' role in cultural traditions, such as ritual calculations and symmetrical designs in indigenous art. By incorporating these three aspects, this study develops a mathematics curriculum tailored to Indigenous students' cultural backgrounds, fostering greater engagement and meaningful learning experiences.

Research Methodology

This study adopts a case study approach to examine the development of a culturally embedded mathematics curriculum at an indigenous school in Taiwan. The research focuses on designing and implementing mathematical tasks that integrate symbolic, social, and cultural components, based

on Bishop's (1988) mathematical enculturation framework. By embedding cultural knowledge into mathematics learning, this study aims to enhance students' engagement, mathematical understanding, and cultural identity.

The study is conducted at an indigenous junior high school, Padan Asang School, in Taiwan, focusing on a ninth-grade class. Padan Asang School is a pioneering indigenous experimental school located in southern Taiwan. It was selected as the research site due to its distinctive approach to designing mathematics curricula and tasks. Rooted in the Bunun culture that the school actively promotes, its mathematics curriculum is fundamentally shaped by Bunun heritage, knowledge systems, and worldview. The participants include school principal, mathematics teachers and cultural experts (local elders and artisans). The selection of this school was based on the school's existing efforts in cultural integration, the community's strong interest in cultural preservation, and the need to improve indigenous students' engagement in mathematics. The mathematics curriculum integrates classroom-based mathematical instruction, outdoor experiential learning and community and cultural involvement. This study employs qualitative research methods for data collection, including classroom observations, the interviews of teacher and cultural experts, and student learning artifacts. Data will be analyzed using thematic analysis, focusing on task performance in mathematical problem-solving.

Results and Conclusion

Bishop (1988) proposed that mathematics curricula should consist of three key components: symbolic, social, and cultural. These elements help connect students' mathematical learning with their cultural background and daily experiences. This analysis examines the Three-Stone Stove unit in the mathematics curriculum, evaluating how its mathematical content aligns with Bishop's framework.

According to an interview with one of the school directors who designed and led the Three-Stone Stove unit, the purpose of incorporating this traditional cooking method into the mathematics curriculum was to show students that mathematics is not a distant or abstract subject, but rather one that is deeply embedded in everyday life—even in ancient wisdom. The Three-Stone Stove is a device commonly used in Bunun culinary traditions. By arranging three stones in a triangular formation, the Bunun people are able to place a cooking pot securely on top, creating three stable points of support.

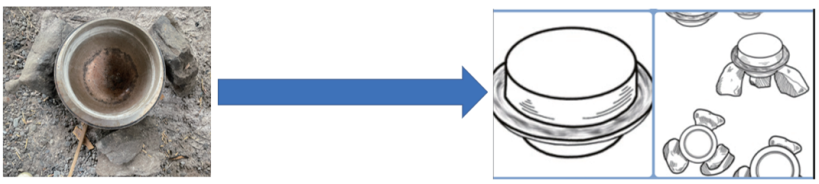
To ensure even heating of the stove and the food inside, students needed to consider several practical factors: the distance between each stone to maintain balance and prevent the pot from tipping over, the optimal location for placing tinder to distribute heat evenly, and how to avoid overheating or burning certain parts of the stove. These real-life challenges required students to apply their knowledge of mathematics and science.

According to the director's observations, students who participated in the unit posed more mathematical and scientific questions during the hands-on activities. This engagement helped them develop inquiry-based thinking and apply their academic knowledge to practical problem-solving scenarios.

As for the three key components of mathematics curricula, they are analyzed as follows. The symbolic component refers to mathematical representations, structures, and notations. In the Three-Stone Stove unit, symbolic components include geometric structures, shape recognition, measure-

ment, heat conduction, and numerical calculations. Students analyzed the circular, triangular, and polygonal arrangements of stones and applied angle measurements and symmetry principles to understand their stability. Through hands-on activities, students needed to measure stone sizes and distances. The social component emphasizes mathematics in everyday life, trade, and community interactions. In this unit, real-world applications include cooking, ecology and resource efficiency. Students calculated fuel-burning times and cooking durations, applying time measurement, ratios, and speed calculations. Students collaborated in teams to analyze efficiency variations across different stove configurations by collecting data, conducting statistical comparisons, and presenting their findings through graphical representations. These activities demonstrated the practical value of mathematics, enhancing students' ability to apply mathematical concepts in social and environmental contexts.

The cultural component explores how mathematics preserves indigenous knowledge, history, and values. The Three-Stone Stove unit integrated culture and mathematics in the following ways. Firstly, the lesson highlighted how indigenous communities select appropriate stone materials based on resources, introducing students to select optimization strategies. Secondly, by tracing the evolution of Three-Stone Stoves in tribal communities, students learned how traditional cooking methods influenced early mathematical calculations related to heat efficiency. Finally, the arrangement of three stones not only is functional but also follows symmetry and stability principles. Students applied mathematical calculations to assess structural balance and efficiency. These cultural connections enhance students' appreciation of indigenous mathematical knowledge, fostering both academic learning and cultural identity.



Cultural Event:
The three-stone stove holds deep meaning and symbolism in Bunun culture, reflecting the people's respect for nature and wisdom. Composed of three stones forming a stable support, the three-stone hearth symbolizes stability and harmony. It is not only a daily cooking tool but also the center of family life. Activities such as cooking, gatherings, and rituals take place around it, strengthening emotional connections among family members. On a spiritual level, the three-stone hearth represents the continuation of life and the wisdom of ancestors. Each year, before important festivals, the people rekindle the fire, a ritual that is not only a reverence for fire but also an expression of respect for ancestral spirits.

Mathematical Task:
The three-stone stove is composed of three stones of approximately equal height, arranged in a triangular formation to create a stable support structure. This design utilizes which principle of triangles to ensure that the pot can be securely placed on top? Additionally, where should the fire be positioned within the triangle?

Figure 1. Mathematical task of the three-stone stove

This unit enhances students' mathematical skills while reinforcing indigenous cultural knowledge, providing a valuable model for culturally responsive mathematics education.

Based on this analysis, the following recommendations are proposed for future curriculum development and implementation. Researchers encourage the use of local artifacts, tools, and oral traditions to enhance learning experiences. Through project-based learning, mathematics teachers should allow students to apply mathematics to real-world indigenous living settings. Mathematics teachers attempts to extend the use of indigenous knowledge and practices to other mathematical topics.

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TSG8-06

A PRACTICAL STUDY ON THE INDIGENOUS RITUAL CULTURE IN ELEMENTARY SCHOOL INQUIRY EDUCATION

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Taiwan is a multicultural society based on respect for indigenous peoples. The 12-year basic education curriculum aims to enhance the understanding of multicultural education for all students and the ethnic education needs of indigenous students. It adopts regulations related to indigenous peoples in the overall curriculum framework, implementation points and learning priorities of each curriculum. The guidelines further incorporate inquiry into the core curriculum of primary and secondary schools to connect students' culturally relevant life experiences. This study first explores the literature content of cultural response theory, curriculum standards, inquiry-based teaching courses, etc. to strengthen the theoretical foundation of curriculum design; then, based on the core, learning focus and inquiry-based teaching of the natural science domain in the 12-year national education curriculum, the Paiwan people's five-year traditional festival - thorny rattan balls are integrated into the concepts of force and motion in the sixth grade of elementary school, enhancing students' understanding of the wonderful use of science in Paiwan culture, understanding the concept of the lever theorem unit, and cultivating the ability of inductive reasoning. We hope that this course design can effectively help domestic indigenous students increase their interest in learning, help them recognize and affirm their own unique culture, and convey this study's respect and care for multiculturalism.

Keywords: Culturally responsive teaching, curriculum standards, 5E inquiry teaching

Introduction

Taiwan's indigenous peoples have their own unique culture, which is different from that of the Han Chinese. International reform movement Multicultural education, the practice of culturally responsive teaching developed in response to the needs of various ethnic groups, cultivates students' cultural integrity, personal abilities and academic achievements (Gay 2010, Ladson-Billings 1995a)

As science education in the United States develops towards multiculturalism, science education for indigenous peoples is increasingly valued. For example, Project 2061, a science reform education project under the U.S. education reform plan, and the Position Statement on Multicultural Science Education of the National Science Teachers Association (NSTA) (2000) actively advocate that science education should incorporate the spirit of multiculturalism and emphasize that science education should enable all students from different cultural groups to have the opportunity to learn science and obtain employment opportunities in the fields of science, engineering and technology (Fu Liyu 2006). The above shows that traditional culture and mathematical science education have a great influence.

Articles 14 and 15 of the United Nations Declaration on the Rights of Indigenous Peoples [UNDRIP], adopted by the United Nations General Assembly in 2007, assert that indigenous peoples have the right to have their culture, traditions and history appropriately reflected in education, and that states should work with indigenous peoples to take effective measures to ensure that indigenous

children have the opportunity to receive education about their own culture in their own language. In accordance with the Indigenous Education Act and the 108 Curriculum, Indigenous issues are integrated into the mathematics and science curriculum. This article proposes a curriculum design that integrates culturally responsive teaching into 5E inquiry teaching to allow Indigenous students to connect tribal life culture with science, and hopes to provide suggestions to assist front-line teachers in their professional development.

The purpose of this study is to:

(i) Providing opportunities for indigenous students to learn through inquiry and solve problems, and to develop scientific knowledge and skills; Develop a scientific thinking system and a habit of scientific inquiry, develop a positive scientific attitude, and develop a scientific core concept.

(ii) This course provides a multicultural learning environment through the culturally responsive scientific teaching materials and diversely designed teaching activities. It combines students' cultural backgrounds, community resources, and school teaching resources to allow students to come into contact with local culture and knowledge, and to develop interest and motivation in learning.

Literature Review

Multicultural education is an emerging educational reform movement that can be traced back to the civil rights movement of African Americans in the 1960s in the United States. Taiwan's multiculturalism was influenced by the democratization and localization trends after the lifting of martial law (Tan Guangding, Liu Meihui, and You Meihui 2015). Multiculturalism believes that the traditional wisdom contained in indigenous science is that indigenous tribes will develop practical knowledge that is closely related to their living environment and is essential for the daily survival of the ethnic group. Since the 1980s, educational researchers have begun to incorporate a social perspective into their view of natural subjects and culture, shifting their thinking from psychological knowledge or cognitive models to the view that learning is based on social interaction (Lerman 2000).

The concept of culturally responsive teaching emerged in the 1970s, and scholars have used different terms to refer to this concept, such as culturally appropriate (Au & Jordan 1981), culturally relevant (Ladson-Billings 1995b), and culturally responsive (Gay 2003). It means that classroom teaching can refer to the characteristics of the student group, consider the students' cultural background and learning style in curriculum and teaching, use the students' native culture as a bridge for learning, and help students with cultural differences have a fairer opportunity to pursue excellent performance (Gay 2000).

In recent years, the United States has also released a new curriculum for science education - the Next Generation Science Standards (NGSS), which emphasizes the integration and application of core concepts and practices (NGSS Lead States 2013). The "108 Curriculum" announced by Taiwan in 2018 emphasizes the teaching of core competencies. In order to make up for the fact that the old nine-year curriculum did not include ethnic education in the national curriculum, it attempts to improve the situation where the "Nine-Year Curriculum Outline" has no regulations on ethnic education other than "indigenous languages."

Research Method

The research method of this study is case study method. The research subjects were a class of sixth grade students in an indigenous elementary school in Pingtung County (the class had only 19 students). The teaching activity design and teaching unit are the mechanics unit for sixth graders in elementary school, and the teaching method adopts 5E inquiry teaching. During the research process, the teacher serves as the course designer, teacher and observer. During the teaching process, a research participant is also arranged to provide the teacher with teaching suggestions and feedback to help the teacher continuously correct his teaching skills and research direction. The research data collection includes: classroom observation video, document analysis (interviews, study sheets), researcher notes, teaching suggestions and feedback from teaching observers, and a student course feedback sheet.

Data Collection and Analysis

The researchers incorporated the Paiwan tribe's traditional ritual, the five-year rattan ball festival, into the sixth grade science inquiry teaching activities of lever setting. After each teaching activity, the students recorded their own views on the teaching activity and the problems they found, and conducted self-reflection and understanding. The data in the notes are represented by JT, and the following four digits represent the date.

Group Sharing and Discussion

All students were interviewed in groups about their views on the scientific concepts of each teaching topic and the five-year festival activities. Since the researchers were not teachers in the case schools, they were not clear about the students' situation in the case schools. In addition, considering the psychological factors of students' shyness and the hope that students could stimulate their ideas through peer stimulation, this study adopted the group interview method. The group sharing and discussion data were represented by TR, and the following digits represented the student number. Two to three comprehensive interviews were conducted with the students.

Results

This study takes the five-year ritual of rattan ball in the Paiwan culture as its target. 5E Science Inquiry allows students to understand the basic principles of the lever theorem, understand the force point, resistance point, force arm and resistance arm of the rattan ball pole; in mathematics, the concept of proportion calculation is applied to understand how to produce the phenomenon of saving effort and exerting effort.

The Benefits of Providing Culturally Responsive Instruction as an Inquiry Curriculum

As students engage in science activities, they work together, share and discuss different perspectives, and in the process learn about their cultural similarities and differences, as well as how others view science and use scientific knowledge, perspectives that connect to the inquiry-based practices we want students to develop in science classes. Based on the results of the interview and hands-on inquiry experiment, students mentioned their ideas for the cultural response and inquiry courses: "*This time, the Quinquennial Festival thorn ball game is actually related to natural science. The teacher also asked us to do it by ourselves to find the force application point, resistance point and fulcrum. It was really interesting" (TR01); "From the results, we explored which type of lever theorem is labor-saving? Which type is labor-intensive? Which type is time-saving? They are all*

related to the Quinquennial Festival" (TR10). "Today, through the experiment, I learned about the lever theorem and three of its terms: the fulcrum, the point of force application, and the different positions of the force application points. Different forces must be used. The sacrificial poles used in our ancestors' five-year sacrifices are also related to this. This is something I didn't know before. I thought the tribal warriors must have great skills in stabbing the lucky ball. This is related to the lever theorem that the teacher taught in class" (TR18).

In Terms of Culturally Responsive Teaching

In terms of culturally responsive teaching, teachers should understand the cultural implications behind the behavior of indigenous students and incorporate students' cultural differences into the design and methods of teaching preparation and implementation, so as to adopt educational activities that are in line with the characteristics of diverse ethnic groups in a multicultural school context, create opportunities conducive to learning, and further promote learning development. Researchers believe that culturally responsive teaching is not just a teaching method, but an attitude towards students and a driving force for redefining the roles of teachers and students. It is also a tool for school reform and an empowerment mechanism. It is suitable for different types of schools, and all students can benefit from this teaching.

In Scientific Inquiry Learning

Today, my country's 108 curriculum emphasizes that inquiry-based teaching strategies should be included in curriculum design and actual teaching. We can understand that the cultivation of scientific inquiry ability has become an important topic in my country's science education; allowing students to learn science in a natural and real situation like scientists. Many modern courses also emphasize allowing students to learn in real situations like scientists. The model of scientific learning is inquiry-based. Students' learning must take place through events that happen around them or that they experience and comprehend, so as to arouse their interest in learning and enable them to explore scientific knowledge or make decisions and solve problems. When conducting scientific learning, we should pay attention to students' actual living world and conduct natural course learning from real situations, avoiding the crisis of scientific learning caused by emphasizing only empirical science.

TSG8-07

SURVEY AND STUDY OF "ETSUKI-SANGAKU," MATHEMATICAL TABLETS WITH ILLUSTRATIONS, IN FUKUI PREFECTURE, JAPAN, AND EMPIRICAL RESEARCH ON ITS UTILIZATION FOR MATHEMATICS EDUCATION

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This is a study of the cultural and educational phenomenon of distinctive Japanese mathematics ("Wasan," established in early-modern Japan by Seki Takakazu) dedicated to local shrines and temples from the Edo to Meiji periods. As a legacy of Wasan, throughout Japan, there exist more than 900 "sangaku"-like mathematical tablets (academic plaques with math problems, answers and solutions displayed. Many sangaku feature geometric problems, but others present algebra, surveying and Buddhist problems). Referring to previous studies on the teaching materials of the history of math, we aimed to attract students' interest by making them aware of the existence of "Etsuki-sangaku" (mathematical tablets with illustrations depicting real-world scenes of math problems) in Fukui prefecture, as a heritage of science in the school district and neighboring areas, and by directing their attention to the thoughts and ideas contained therein and beyond. In addition, students can explore original sources within their school curriculum in an interdisciplinary way and apply them to shape their own learning. This paper presents a proposal derived from practical research in mathematics education using "Etsuki-sangaku." Five suggestions emerged from this research.

Keywords: Japanese Mathematics "Wasan", Mathematical Tablets "Sangaku," Mathematical Tablet Cultural Studies, Fukui Prefecture

Introduction

The number of extant mathematical tablets from shrines in Fukui prefecture is 23. Of those, only 12 have illustrations (and are thus "*Etsuki-sangaku,*" hereafter "*E-S*"), so they are the focus of this study. We first classify the mathematical features of the 12 *E-S* (mathematical tablets with illustrations), all of which come from shrines in Fukui's Tannan region.

The term *E-S* is based on the original text of the Oshio Hachiman Shrine's "Crane, Turtle, Pine, and Bamboo tablet" (1701), shown in Figure 1, entitled "Etsuki Sanjyustu no Ichimon." We define *E-S* as "mathematical tablets with illustrations in which all/part of the title is pictorialized and, though the problem cannot be misinterpreted without the picture, the picture leads to an understanding of the scene or adds an intention to record or commemorate an event by the donor or hometown."

Based on the research results of these *E-S* in Fukui, we will develop teaching materials for math education, and assess their applicability through empirical studies conducted by classroom research.

Figure 1. Etsuki-Sangaku of Oshio Hachiman Shrine (1701)

Purposes and Methods of the Study

The purposes are to classify the 12 *E-S* in Fukui prefecture by their particular mathematical features, and then to develop them as teaching materials for math education. A summary follows of the features of the 12 *E-S* based on previous research, written records, visual inspection and image data. Based on the research results, we develop teaching materials for math education, conduct empirical research through classroom studies, and obtain suggestions on the potential for using the materials for contemporary math education.

Research Contents and Results

Distinct Disposition of Fukui's Etsuki-sangaku

The 12 mathematical problems of Fukui's *E-S* can be subdivided into 8 problems of higher order equations, 2 problems of least common multiple, 1 problem of quadrature of forfeiture, and 1 problem related to Buddhism (Mt. Sumeru). The *E-S* in Figure 1 is unique in that the side illustrations were done first, and then the math problem was written in the center, incorporating the dedicatee's own age of 75 years as the age of the bamboo, thus incorporating real-life meaning to the question. The 4 *E-S* from Sabae City all depict local shrines and have cultural value as a record of the local area. In these ways, Fukui's 12 *E-S* can also be classified into 7 distinct patterns of artistic arrangement.

Figure 2. Etsuki-sangaku of Ishibe Shrine
(image courtesy of the Sabae City Board of Education, Cultural Division)

First Question of the Etsuki-sangaku of the Ishibe Shrine (1877)

The question posed is that the shrine has received 2 big wooden barrels of sake containing 2000 *gou* [1 *gou* ≒ 180mL]. The number of shrine parishioners is 307, and the number of female parishioners is 3 fewer than the males. Moreover, females should each receive 3 *gou* of sake less than the males. Find how much sake each male and female receive. This problem has pleasing symmetry because it features the number 3 twice. In fact, the answer is males receive 8 *gou* and females 5, and the population is 155 males and 152 females. The population of Kitanakayama-village, Ōaza Isobe (the former Isobe-village, where Ishibe Shrine is located) in 1891 is given as 164 males and 165 females in the *Japan Place Names Dictionary* (*Kadokawa Nihon Chimei Daijiten,* 1989, 18, p. 140), so the question probably incorporated the village's actual population at that time.

Implications of Etsuki-sangaku for Mathematics Education

In the 2008 editions of 7 Japan's authorized textbooks for junior high school math, all publishing companies included figures of *sangaku*, but in the 2021 and 2025 editions, the number decreased to 4 out of 7. Collaborating with the Sabae City Board of Education, we designated the X Junior High School District a pilot district and conducted a multi-year/longitudinal program of on-site classes at 4 elementary schools and 1 junior high school, studying the Ishibe Shrine *E-S* (Figure 2) from the interdisciplinary viewpoints of mathematical and cultural/historical significance. The solution method in the text of the time assumes that all people are men, and it is like the famous "Crane and Tortoise Calculation", so to understand the solution method, the original text "Algorithm Point-by-Point Guide" by Sakabe (1815, Intro, Prob. 32) was also used as a teaching material. The problem statement is a quadratic equation with 4 variables, but the students realized it could be reduced to a linear equation with 2 variables. The class structure, of three 50-min. periods, was as follows:

(1) Observation of *Etsuki-sangaku* and understanding of the math problems

(2) Self-solving

(3) Comparison of students' mathematical thinking and solutions with the *Etsuki-sangaku* ones

(4) Creating new problems by changing the conditions (following the "what-if-not" strategies of Brown & Walter, 1990; 1993)

(5) Creating original, contemporary *Etsuki-sangaku* or *sangaku*.

(1) (2)(3): Activities like a historian of mathematics; (4)(5): Activities like a mathematician

As such, it is a highly literal iteration of problem-posing and inquiry education, in which students can participate actively and shape their own learning, while gaining pride in and appreciation of Japan's unique and beautiful mathematical cultural heritage through local artefacts (as a form of interdisciplinary learning). Through such "mathematical enculturation" (Bishop, 1991), we can "humanize" and personalize math, helping students feel less of a cultural gap with their ancestors.

Results and Conclusion

A post-activity questionnaire administered to 268 junior-high students revealed the following findings. The material has not yet been generalized to wider populations, but this is the future goal.

The study introduced the concept of Japanese mathematics (*Wasan*) for the first time to more than half of the students. The students became able to explore the mathematical ideas/methods found in the *E-S*, in contrast to contemporary math techniques, and thus became able to appreciate the high

quality of the mathematical ideas. This encouraged students to show interest in learning Japanese mathematics and other mathematical histories/heritages. They reported their enjoyment in doing the activity and their realization of the difficulty of creating challenging math problems and thus their respect for the *sangaku* creators. Many students have come to think appreciatively/nostalgically about *Wasan* and have thus enriched, improved, or broadened their views of the math they learn at school.

We obtained the following five suggestions, although they have not yet been generalized.

- Our ancestors bequeathed a wealth of research material; obtaining primary documents and modern-language translations is easy. Japan has over 900 extant *sangaku*, so visiting them is possible. Organizing and presenting the activities and calculations of the school district is likely to increase interest in the heritage of science and increase local understanding and pride.
- By referring to the readily comprehensible *E-S* as primary documents, students can explore the solutions found in the calculations and the technical documents of the calculations of the time, and to appreciate the merits of hypothetical methods through solution comparison.
- Referring to *E-S*, creating problems that include illustrations in the making of *sangaku* will promote an understanding of the perspectives and feelings of the donators of the *sangaku*.
- It broadens and improves the way in which math is perceived (mathematics view) in schools.
- While it is difficult to secure class time, a single lesson is insufficient, so it is necessary to create problems throughout the unit and year, and "*Wasan* utilization." Moreover, it is necessary for math teachers to work with local researchers etc. to understand the reading of primary sources and the methods for solving problems at the time, and to find ways to cover this material without increasing the number of hours.

Building on this study, it is hoped that students will show interest in the existence of mathematics and experience the wonder of Japanese culture in such interactive and interdisciplinary ways.

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KOREA 2025 수학

EARCOME9

The 9th ICMI-East Asia Regional Conference on Mathematics Education

Topic Study Groups 8
(Day 3)

TSG8-08

SURVIVING MASTERY IN MATHEMATICS EDUCATION

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In mathematics education we are no stranger to the word "mastery" as we are constantly in pursuit of some form of mastery, for both teachers and students. The notion of mastery has been and continues to be implicitly embedded in our teaching and learning practices. We show how this has produced various forms of marginalization, particularly with respect to race and gender. Even as we, the authors, try to overcome or undo the practices of mastery, we find ourselves caught up in new forms of mastery. Thus, in this theoretical paper, we explore the entanglement of mastery in mathematics education and its implications; we then offer some speculations on ways to survive mastery.

Keywords: mastery, race, gender

Our interest in challenging the notion of mastery began with our reading of Julietta Singh's *Unthinking Mastery* (2017), an unconventional read for a mathematics education book club, but one that caused much reflection to occur. Within the first few pages, we were drawn in when she wrote, "mastery's obdurate presence necessarily affects how scholars within and beyond the postcolonial project envision their intellectual pursuits today" (p. 2). We became curious to explore how her ideas would play out in mathematics education which Singh did not discuss in her work.

As a student, one common narrative the second author heard in her classrooms was around boys being better at mathematics than girls. It also manifested in the form of surprised looks from teachers whenever she outperformed the boys. In retrospect, the second author was unaware of the implicit mastery at play at that time but was eager to negate the claim, which unfortunately led to the reproduction of mastery. For the first author, mastery showed up in a different form, one that many may perceive as being positive. As a South Asian female, it was presumed that she would excel in mathematics due to the underlying belief that all Asians do well in mathematics. Thus, even when struggling with mathematics, that struggle was never shown as it was a societal expectation that South Asians should attain mastery in mathematics easily. Thus, reflecting and realising the extent mastery is embedded in our lived experiences, we were both drawn to the idea of exploring how we could limit our desires for mastery and resist perpetuating some of the mastery practices inherent in the teaching and learning of mathematics.

In *The Mastery of Reason*, Valerie Walkerdine (1988) also questioned specifically if mathematics' mastery over the world was achievable and at what cost. She asked, "if mathematics provides a dream of an ordered and pure universe, rational and unsullied by the passions … what kind of pleasure is the pleasure afforded by mathematics?" (p. 189). A possible response to this question—which many mathematics educators would offer—would be: the pleasure of mastery. A bold statement, but what exactly does mastery entail?

Ways of Thinking about Mastery

Before we look at the relation of mastery to mathematics education, we will first reflect on the concept of mastery. One of the most common ways of thinking about mastery involves the idea of domination, which follows from the oldest meaning of a master as "someone who had bested an opponent or competitor, or someone who had achieved a level of competence at a particular skill to become a teacher of it" (Singh, 2017, p. 9). In other words, mastery implies that one has full control over something (human or non-human) and the right to impose one's perspectives on them, with colonisation being one of the most classic examples of mastery at play. Through colonisation, force was used to spread dominant race beliefs, and accepted through the power mastery holds. But over time, practices of mastery have shifted, operating less with respect to only one master (be it a single entity or a single collective) and about owning people but more with multitude of collectives owning land, ideas and values, while retaining certain key aspects of the original idea of mastery. Hence, it might be helpful to understand what these key aspects are without trying to define mastery as it will be "a gesture toward mastering" mastery (p. 12), which we would like to avoid in our attempt to unthink mastery. Mastery often results in some form of *separation* or *division by force*, which creates *practices of subordination* that *unfold and extend over time* (Singh, 2017). For example, in Hegel's notion of the master and slave dialectic, he narrates a story on two "consciousness" engaging in a life and death battle to prove their worth and to gain recognition from the other (Singh, 2017). Eventually, the winner gains control and power over the loser and gets recognised as the master by the loser, who thus becomes the slave. As a result of the battle, not only is the master split off from the slave, but the slave also gets mutilated in the sense of losing itself—its new purpose is to submit to and serve its master. This hierarchical relationship that is formed will continue to unfold across time, until it gets threatened.

Reflecting on Mastery in Mathematics Education

Mathematics is often positioned as a neutral and objective subject with strengths around its universality, certainty and abstractness. Because of these characteristics, mathematics has been and still is glorified by many (Skovsmose, 2023), perceived to possess eternal truths and power to solve all problems, while other subjects taking a subordinate role. As Walkerdine (1988) emphasises, "Mathematics has, for centuries, held this position as queen of the sciences" (p. 187). Moreover, Western-Eurocentric mathematics has been the dominant mathematics while mathematics from the East or the minority communities, including Indigenous mathematics has been suppressed, despite being valuable and useful and have been around for just as long, if not longer. Notably, in his work on ethnomathematics, D'Ambrosio (1985) appealed for us to "look at the history of mathematics in a broader context so as to incorporate in it other possible forms of mathematics" (p. 44). Hence, it is important and necessary for us to challenge this mastery view of (Western) mathematics and see mathematics as a "human construction" that can be and should be "reformed, remoulded and reconstructed" (Skovsmose, 2023, p. 149).

Unfortunately, the mastery view of mathematics has ripple effects on mathematics education, where mathematics has been popularised as a core and necessary subject to be taught in schools, again through Western-Eurocentric forms of teaching. In addition, because of the decontextualized and generalisable nature of mathematics, learners are usually deemed to have "mastered" a mathematical concept when they can abstract the concept from its material and physical contexts and also perform the perceived right way of solving a problem and articulate the ideal structure of reasoning (typically deductive, propositional). Mastery-based expectations have inevitably led to many inclu-

sion issues in our mathematics classrooms as well. In particular, learners are separated into groups where those who are able to adhere to and perform these practices are considered to be more advanced while those who are unable to are considered to be slower.

Moreover, these hierarchies are produced in such a way that align with race, gender and socio-economic status, with marginalised students more often streamed into less valuable courses. Hierarchies found in society based on one's intersectionality being carried forward into the mathematics classroom. In particular, Martin (2009) introduces the racial hierarchy of mathematics ability, which shows how there is a preconceived notion of which races have a better understanding of mathematics and thus will master the complexities of the mathematics classroom. Martin (2009; Martin et al., 2010) argues that the racial hierarchy of mathematics ability is such that Asian and White students will be found at the top of the hierarchy and Indigenous, Black, and Latino populations will be found on the bottom. The consequence for this hierarchical view of mathematics ability is that Indigenous, Black, and Latino populations will perform poorly in higher-level mathematics classes, and hence, become streamed into classes that include easier mathematics concepts (Martin, 2009; Martin et al., 2017). Asian and White populations are assumed to excel in mathematics, positioned as ideal mathematics students whose traits others should emulate.

One may argue that this may be beneficial for the Asian population as they are placed on the higher end of the hierarchy, able to attain mastery more easily, but this placement is also very strategic to uphold mainstream power dynamics. Ernest (1991) writes, "when the power structure of society is physically threatened, force is likely to be brought into play to maintain it" (p. 248). Considering Ernest's words, we believe the perceived hierarchy of mathematics ability is a force used to safeguard white ideologies in mathematics, or forms of mastery. Placing Asian, a racial minority, on the top legitimizes the ideals of the model minority myth, a term used to describe how Asian American Pacific Islanders have successfully adapted to mainstream White American culture, thus not facing any adversity due to race, and consequently not requiring any corrective action which may be required by other races (Banks, 2012). Negating the fact that mathematics may in fact be a white institutional space which becomes safeguarded using the concept of mastery.

Race is not alone in terms of equity in mathematics. Despite evidence suggesting no significant differences between boys' and girls' mathematics performance, there is still the persistent myth about gender differences in mathematics achievements and behaviour where girls' success is often attributed to hard work and rote-learning while boys' playfulness and rule-breaking behaviour are read as intelligence (Robinson-Cimpian et al., 2014). These misconceptions seem to be a result of practices of domination over the female bodies and a perception that "overt challenges to the teachers' authority" (Walkerdine, 1998, p. 209) are indications of brilliance. In fact, as Porter and colleagues (2024) indicated, "teachers' expressed intellectual humility may reduce the gender gap in comfort expressing intellectual humility in school" (p. 15).

Surviving Mastery in Mathematics Education

Although it might be unavoidable that some ways of overcoming mastery involve new forms of mastery themselves, Singh (2017) suggested vulnerability as an approach where "in failure— and critically, in recognizing, reading, and becoming vulnerable to failure—we participate in new emergences, new possibilities for nonmasterful relations" (pp. 174–175). We chose the word surviving for a few reasons. Firstly, given the persistence of mastery in our practices in mathematics education and its entanglement with our lived experiences, it might not be possible to entirely negate

mastery. Thus, we want to simultaneously find ways to live with mastery and to loosen its hold over our assumptions and actions. Also, surviving carries with it the sense that it will not be easy, with many challenges and failures but continuing to maintain hope and finding comfort in discomfort while unthinking mastery. Perhaps the first thing we need to do to survive mastery is to "learn to read for it" (Singh, 2017, p. 7) as we cannot displace the logic of mastery or suggest practical alternatives if we lack the ability to identify it and awareness of how it is produced.

As mathematics researchers and educators, it might involve starting with a critical engagement with our own assumptions of what could be defined as mathematics, what could the goals of mathematics education be, and how could mathematics be learnt. What if the universality and certainty of mathematics is contested? What if the mathematics covered in our curriculum included mathematics from other communities? What if multiple solutions and diverse ways of reasoning were valued and emphasised? But at the same time, we need to be mindful not to perpetuate mastery itself while trying to undo mastery by "producing new masterful subjects" (Singh, 2017, p. 2). This leads us back to where we began with Walkerdine (1988) question of "if mathematics provides a dream of an ordered and pure universe, rational and unsullied by the passions … what kind of pleasure is the pleasure afforded by mathematics?" (p. 189). Perhaps by rethinking the mastery of mathematics, the dream mathematics can offer us is not that of an ordered and certain universe, but, as Whitehead insists, as ultimately contingent on assumptions, only ever providing partial disclosures. Perhaps the pleasure of mathematics can be found through unthinking mastery of mathematics. In other words, there can be truths in mathematics but not necessarily eternal truths and perhaps the route to achieving those truths are not formed on one single person's vision of mastery where exclusion of certain races and gender may occur. Or perhaps, the pleasure lies in speculating what an impure mathematics and universe might look like, one sullied by passions?

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TSG8-09

SECONDARY SCHOOL STUDENTS' LEVEL OF INVENTIVE THINKING IN MATHEMATICAL LEARNING

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In the modern global economy driven by information, technology, and innovation, 21st-century skills are those required of the future worker, such as inventive thinking that comprises six sub-constructs: flexibility, self-regulation, curiosity, creativity, and risk-taking, as well as higher-order thinking. Thus, this study aims to examine the level of 48 secondary school students' inventive thinking based on gender in mathematical learning using a questionnaire which consists of 40 items. Results showed that the level of inventive thinking for self-regulation, curiosity and creativity is high. In contrast, flexibility, risk-taking and higher-order thinking are moderate. Also, the results revealed no statistically significant difference in students' inventive thinking based on gender. This research enhances the worldwide understanding of the influence of gender on creative cognition in educational contexts. Identifying the disparities in creative problem-solving abilities among students of different genders might guide worldwide educational frameworks and policies to promote inclusion and fairness. Such insights may prepare future leaders and innovators globally with the many views essential for addressing intricate global concerns.

Keywords: Inventive thinking, mathematics learning, secondary school students, 21st-century skills, gender.

Introduction

In the 21st century, inventive thinking is one of students' most important cognitive skills when learning mathematics (Peterson & Cohen, 2019). Inventive thinking includes six sub-constructs: flexibility, self-regulation, curiosity, creativity, and risk-taking, as well as higher-order thinking (North Central Regional Educational Laboratory [NCREL], 2002). Although inventive thinking has been integrated, its implementation is insufficient. For instance, most students cannot practice the higher-order thinking skills they have acquired in the classroom (Hidayat, 2021). In addition, many workers in the industry still have less critical thinking skills (Jerome et al., 2017). Past studies also reported no significant differences in inventive thinking skills based on gender (Hasbullah & Mahamod, 2017; Turiman et al., 2020). However, gender differences in mathematical achievements have recently shown a statistical gap becoming smaller and unpredictable over time (World Economic Forum, 2020). Also, the results might vary by location, and 95 per cent of the gender gap is closed globally, with 37 countries already at the same level. Studies on gender differences are often carried out given reports of the shortage of science and mathematics graduates in the global job market, the lack of women participating in the STEM field, and the issue of educational equality (Reilly et al., 2019). Hence, the current study is needed to examine the difference in inventive thinking between male and female students.

Literature Review

According to NCREL (2002), flexibility is the capacity to change thoughts, attitudes, and behaviours in completing a goal within a given amount of time and resources. Self-regulation entails setting objectives, making methods to reach them, managing time, and evaluating results autonomously. Curiosity is the desire to know, which is essential for students to be lifelong learners. Creativity involves thinking about new ideas, solutions, and products. Risk-taking means putting something valuable at risk. Higher-order thinking is a creative problem-solving process that produces educated, sound, thoughtful judgments and conclusions. Students should build these six sub-constructs to prepare them for unpredictable, tough employment and life conditions. Studies on inventive thinking are widely carried out in science, engineering languages and STEM. These studies found that it is important for students to develop these six sub-constructs so that they can deal with complex circumstances on the job as well as in life in this globalized and technologically advanced world (Hasbullah & Mahamod, 2017; Turiman et al., 2020). Nevertheless, studies are still limited to mathematics learning, with few published data on inventive thinking among school students.

Methods

The present study utilized a survey to examine six sub-constructs of inventive thinking among 17 male and 31 female secondary school students. We administered the Inventive Thinking Skills instrument (Arsad, 2011), which has 40 items that cover six sub-constructs of inventive thinking and used a five-point Likert scale (5 for strongly disagree, 4 for disagree, 3 for neutral, 2 for agree, 1 for highly agree). Sample items are 'I am not confident in solving the given problem', 'I like to play, but I am disciplined and do not give up easily' and 'I always come up with new ideas in learning mathematics'. The instrument was assessed for face and content validity by experts. For reliability, we examined the students' responses utilizing Cronbach's Alpha with a 0.938 coefficient value. Using Statistical Package for the Social Sciences (SPSS), the questionnaire data were analyzed through descriptive and inferential statistics.

Results

The results showed high levels of four inventive thinking sub-constructs except for flexibility (M= 3.6424, SD=0.5304), Risk-taking (M=3.4435, SD=0.5280), and higher-order thinking (M=3.6562, SD=0.5224), which revealed mediocrity. Self-regulation has the highest mean (M=4.0231, SD= 0.4786), whereas Risk-taking has the lowest mean (M=3.4435, SD= 0.5280). These findings suggested that mathematics students had a high degree of inventive thinking, which allowed them to think critically and creatively about the problems that needed to be solved so that they could come up with original ideas or solutions. They do an in-depth analysis of the problem, make use of the resources at their disposal, provide suggestions or potential solutions, and ultimately choose the strategy that will be most effective in resolving the issue. High levels of cognitive processing are required for these activities, so students should be given real-life situations to practice exercising their cognitive abilities. This result is consistent with several studies that report that overall inventive thinking skills are satisfactory. The application of inventive thinking skills positively impacts teaching in the classroom (Turiman et al., 2020).

Descriptive statistics showed that male students had higher scores for each sub-construct in inventive thinking than female students (see Table 1). This may be due to several factors. Many mathematical problem-solving activities require students to investigate and use technology-based tools.

Based on recent studies, demonstrating discipline in the STEM field tends to show male students as more creative and self-reliant. According to the larger male variability hypothesis, the results showed that the performance of male students was more variable than female students in most countries. In surveys, males reported having more positive attitudes towards mathematical and scientific subjects, but females reported having lower self-efficacy views (Reilly et al., 2019). The study discovered gender disparities in particular skills alone. Female students take longer to learn than male students (Reilly et al., 2019).

Table 1. Mean and standard deviation for sub-constructs of inventive thinking

	Male		Female	
Subconstruct	Mean	Standard Deviation	Mean	Standard Deviation
Flexibility	3.95	0.471	3.47	0.499
Self-regulation	4.07	0.597	4.00	0.408
Curiosity	3.80	0.641	3.66	0.460
Creativity	3.84	0.639	3.68	0.458
Risk-taking	3.71	0.484	3.29	0.493
Higher-order thinking	3.81	0.472	3.57	0.537

However, the result of the independent t-test showed there was no significant difference in the mean score between the male group (M=3.8765, SD=0.47602) and female group (M=3.6379, SD= 0.36985), with $t(46) = 1.928$, p =.060. The results revealed that both groups had equal inventive thinking skills. Whether male or female, students are all in the same age group. Cognitive processes are similar among younger people, and the brains of younger people tend to light up comparably. According to Nemrawi et al. (2022), the reason there are no significant differences in gender is that all the participants had the same amount of physical development, mental maturity, and previous experience in statistical skills. The results align with those published by other studies (Ramey, 2015), which discovered no gender differences in statistical reasoning ability.

Conclusion

The general degree of inventive thinking among mathematics students was excellent. Except for flexibility, risk-taking, and higher-order thinking, which indicated unsatisfactory results, all sub-constructs of inventive thinking were at a high level. By determining the level of inventiveness among students, policymakers and educators could better devise strategies for inculcating and fostering the required skills. There were no significant gender variations in the degree of creative thinking. We may infer that the pupils' levels of creative thinking were uniform across the board and did not differ depending on gender. Research on gender differences has shown interactions between cognitive abilities and demographic characteristics, including parents' socioeconomic background, age, ethnicity, and educational level. These interactions can lead to exaggerating or underestimating the size of gender differences in some studies.

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TSG8-10

DIVERSE VALUES AND MATHEMATICAL THINKING FOSTERED THROUGH SOCIALLY OPEN-ENDED PROBLEMS: SIMPLIFICATION OF SOCIAL CONTEXTS

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This study aims to examine the impact of simplifying social contexts in socially open-ended problems on children's mathematical thinking and value expression. An experimental lesson was conducted with third-grade elementary school students in Japan using the socially open-ended problem, "Number of Couches Required." The study analyzed the values expressed by the students and the corresponding mathematical reasoning they employed.The findings indicate that even when a socially open-ended problem is presented with a simplified social context, students independently establish assumptions and engage in mathematical reasoning. Furthermore, the simplification of the social context allowed for greater flexibility in lesson time, enabling the introduction of additional problems through modifications of the given conditions. As a result, students were able to present diverse socio-mathematical solutions and actively share various perspectives with their peers.

Keywords: socially open-ended problem, social context, value, mathematical thinking

Introduction

In Japan, research on fostering children's mathematical thinking through mathematically open-ended problems has been extensively conducted (e.g., Hino, 2007). Alongside this, recent studies on mathematical modeling—which applies mathematics to real-world problems—and socio-critical modeling—which critically examines mathematics in societal contexts—have gained attention (Abassian et al., 2020). Socially open-ended problems, emphasizing children's social values, have also increasingly attracted interest, and practical research continues to accumulate (Baba, 2009; González & Chitmun, 2017; Baba & Shimada, 2019).

A representative socially open-ended problem, the "Matoate," has revealed children's diverse values, such as kindness toward younger students, a value reported as uniquely Japanese (Baba & Shimada, 2019; Shimada, 2017). Japanese educational culture emphasizes care for others, represented by "wa" (harmony) (Benedict, 1946). The "Matoate" incorporates strong social contexts, including school festival activities, participants being first graders, and point-based rewards, clearly expressing children's values (Shimada, 2017).

However, implementing such problems can require significant class time for students to understand them, limiting time for mathematical thinking. Teachers also face challenges deciding how much real-world context to include. Simplified socially open-ended problems, if effective in eliciting chil-

dren's diverse values and mathematical thinking, could ease the teachers' burden in lesson preparation and allow exploration of multiple meaningful solutions.

This study examines how simplifying social contexts in socially open-ended problems affects children's mathematical thinking and values expression. Using the "Number of couches required" problem (Hattori, Fukuda & Baba, 2021), we analyze children's expressed values and their mathematical thinking.

The Socially Open-Ended Problem: "Number of Couches Required "

Socially open-ended problems are defined as "problems that aim to cultivate social judgment through mathematical thinking and allow for mathematically and socially diverse solutions" (Baba, 2009, p. 52). They explicitly highlight students' social values and promote diverse mathematical thinking and solutions in the classroom. Shimada and Baba (2022) introduced the problem "How many chairs are needed?", which is structured as follows:

In the school auditorium, chairs are arranged to seat a class of 36 students. Each chair seats five students. How many chairs are needed?

The social context in this problem is embedded in the setting of a school auditorium used for school events. This setting was chosen because students are familiar with the space, understand its typical usage in school events, and have a concrete sense of its dimensions. Such considerations enable students to propose a range of socially and mathematically diverse solutions based on their values.

In contrast, the socially open-ended problem "Number of couches required", used in the experimental lessons of this study, shares the same fundamental mathematical structure as the problem introduced by Shimada and Baba (2022) and was previously presented in Hattori et al. (2021). The problem statement is simple:

There are 30 children. How many couches, each seating up to four people, should be available?

This means that no specific location, such as a gymnasium or classroom, was designated, nor was the grade level of the children explicitly specified.

Classroom Implementation and Analysis

The lesson was conducted in January 2025 at a public elementary school in Japan. The criteria for selecting participants were based on students in the third grade who were learning "division with remainders." As there was only one third-grade class at the school, all 17 students in that class participated in the study. Regarding the data collection procedures, a video camera was set up at the back of the classroom to record both video and audio during the lesson. For the data analysis process, students' worksheets were collected after the lesson, and both the worksheets and the video recordings were closely analyzed.

First, we provide an overview of the lesson. The teacher presented the problem and instructed the students to first write their ideas on a worksheet. With the exception of one student[3], all students used either the calculation $30 \div 4 = 7$ remainder 2 or $4 \times 8 = 32$ to determine their answers. The teacher then called on several students and confirmed that $30 \div 4 = 7$ remainder 2 led to an answer of 8 benches. The teacher also illustrated the arrangement on the blackboard and confirmed with the students that only two students would sit on the last couch. Following this, the teacher asked, "Are there any other ways to arrange the seating?" In response, one student asked, "Do we have to seat

exactly four people on each couch?" The teacher replied, "That's up to you," and encouraged the students to consider alternative solutions. Additionally, they were instructed to describe the advantages of their seating arrangements.

Here are some representative responses recorded on the students' worksheets. Student B wrote, "If five people sit on one couch, we need six couches," and used a diagram to illustrate their reasoning. They also wrote, "It's a tight fit, though?" Similarly, Student J arrived at the same conclusion and noted the advantage, "It reduces the number of couches needed." This reflects an efficiency-oriented value, where students, assuming they are small-sized elementary school children, adjusted the standard four-person seating to five people per couch to minimize the total number of couches required. Since the problem's social context was simplified, the students were not given an explicit age for those sitting on the couches. In the lesson, they naturally assumed that the people sitting were their own third-grade classmates, effectively setting the conditions themselves. Student C responded with "30 ÷ 1 = 30, so 30 couches," explaining, "Each person gets their own couch. It's spacious." Student G shared a similar idea, stating, "Each person can relax on their own couch." These responses reflect a comfort-oriented value, where individual space is prioritized. Additionally, Student C also recorded another response: "30 ÷ 2 = 15, so 15 couches," explaining, "Two people can sit together and chat." This suggests an emphasis on social interaction, where students value the opportunity for communication and engagement with peers. Student H proposed "If three people sit on each couch, then 30 ÷ 3 = 10, so 10 couches," adding, "It's more spacious." This response also aligns with the comfort-oriented value, prioritizing a balance between space and seating arrangements. Furthermore, Student K used a diagram to illustrate their reasoning (Figure 1). This response follows the calculation 4 × 6 + 3 × 2 = 30, meaning that six couches seat four students each, while two couches seat three students each, resulting in a total of eight couches. Since the worksheet did not explicitly state the reasoning behind this choice, the teacher conducted a post-lesson interview with the student. During the interview, the student explained, "Rather than seating 4, 4, 4, 4, 4, 4, 4, and 2, I thought that creating groups of three would make the difference between the groups of four and the other students smaller." This response reflects a consideration of balancing group sizes, demonstrating an awareness of fairness in seating distribution.

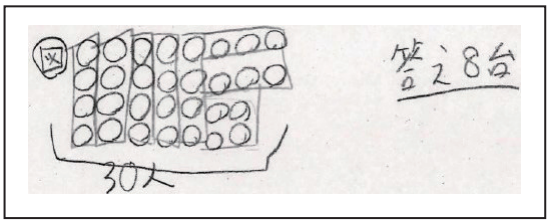

Figure 1. Student K's worksheet response

The teacher had the students present their ideas recorded on the worksheets and shared them with the entire class. Following this, the teacher asked, "What kind of seating arrangement would be best during the COVID-19 pandemic?" One student responded, "30 ÷ 1 would be best because it would reduce the risk of spreading illness." In the latter part of the lesson, the students were asked to consider how many couches would be needed if the problem statement specified 29 children instead of 30 (Brown & Walter, 2005). While many students answered 29 ÷ 4 = 7 remainder 1, leading to a total of 8 couches, some students provided alternative responses. Student E responded: "I wanted to use a number smaller than four so that everyone could sit in equal groups, but since numbers small-

er than four do not divide evenly, it's not possible. So, I used 29 ÷ 3 = 9 remainder 2, which gives an answer of 10 couches." This response demonstrates a concern for fairness, as Student E explicitly aimed to ensure that all students sat in equal groups. This aligns with the findings of Baba & Shimada (2019), where students similarly expressed a fairness-oriented value. Student H responded: "29 ÷ 2 = 14 remainder 1, so the answer is 15 benches. The good thing about this is that two people can talk to each other, and when someone isn't feeling well, they are less likely to spread their illness to others." This response reflects a dual consideration of social interaction (the benefit of conversing with a partner) and health awareness (maintaining physical distance to prevent illness transmission). Student H demonstrated an ability to integrate multiple social perspectives into their mathematical reasoning.

Conclusion

In this study, we are not asserting that a social context is unnecessary for students to reach mathematical solutions based on their values. Rather, we aimed to investigate whether students' values would still emerge even when the social context was simplified. As a result, we found that even with a minimized context, students were able to independently create their own social contexts. Moreover, the interaction between students and the teacher played a crucial role in enriching the simplified context with social dimensions, enabling the sharing of diverse values. Furthermore, simplifying the social context allowed for more flexibility in lesson time, making it possible to introduce additional variations of the problem by modifying its conditions. These variations also elicited a range of socially and mathematically diverse responses from students, facilitating the sharing of different perspectives among peers. Of course, it remains uncertain whether the social context can be simplified for all socially open-ended problems while still maintaining their effectiveness. Therefore, further accumulation of practical research is necessary to explore the broader applicability of this approach.

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TSG8-11

DIGITAL MATHEMATICS STORYTELLING IN INDONESIA, VIETNAM, AND THE ASIAN DIASPORA: EQUITY, CULTURE, AND COMMUNITY THROUGH NARRATIVE IDENTITIES

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This paper explores the use of Digital Mathematics Storytelling (DMST) as a transformative pedagogical approach to addressing equity and culture in mathematics education in Indonesia, Vietnam, and broader East Asian contexts. Through community storycircles focused on counter-storytelling, DMST engages students and teachers in creating digital stories that surface community-based mathematical knowledge, counter dominant narratives, and foster identity development. Drawing on our studies in Indonesia, Vietnam, and Asian American communities in the USA, this paper highlights how DMST disrupts Eurocentric mathematics education by recognizing culturally sustaining knowledge and practices. DMST provides a unique pathway for fostering equity by amplifying marginalized voices, facilitating counter-storytelling, and integrating mathematical learning with cultural knowledge.

Keywords: Digital Mathematics Storytelling, Narrative Identity, Counter Storytelling, Indonesia, Vietnam

Mathematics education in East Asian countries has long been influenced by global educational discourses that prioritizes standardized achievement and decontextualized mathematics instruction. While many East Asian nations perform well in international assessments, such as PISA and TIMSS, the emphasis on procedural fluency frequently marginalizes the rich mathematical knowl-

edge embedded in local cultures and everyday practices. Furthermore, issues of equity arise as marginalized communities—whether due to ethnicity, socioeconomic status, or geographic location—often lack access to pedagogical approaches that affirm their cultural identities. Digital Mathematics Storytelling (DMST), a method centering upon the creative act of storytelling to explore one's own identity, can serve as a powerful creator of counter-narrative to these dominant (and colonizing) modes of teaching and learning, offering an approach that centers student voice, cultural knowledge, and digital media literacy.

Therefore, the objective of this paper involved examining how Digital Mathematics Storytelling (DMST) engages students and teachers in culturally embedded mathematical knowledge, constructing narrative identities, and challenging dominant narratives in mathematics. Specifically, we asked: (1) How does DMST support culturally relevant and sustaining pedagogy in mathematics? (2) How does the digital modality empower marginalized voices in narrating mathematical experiences?

Theoretical Framework

Our draws upon three case studies of Digital Mathematics Storytelling workshops with students and teachers grounded in four interconnected theoretical lenses:

1. Culturally Sustaining Pedagogy (CSP): DMST provides a structure for participants to preserve and evolve their cultural knowledge by embedding mathematical learning within local traditions and lived realities (Paris & Alim, 2017).
2. Counter-Storytelling: By enabling students to challenge dominant narratives (e.g., that mathematics is culture-free), DMST serves as a vehicle for marginalized voices to share mathematics through critical, lived experiences (Solorzano & Yosso, 2001).
3. Narrative Identity: Participants craft stories that reflect and construct their identities, positioning mathematics as personally meaningful rather than abstract and imposed (Sfard & Prusak, 2005).
4. Funds of Knowledge: DMST draws on home- and community-based knowledge systems, situating mathematics within everyday cultural practices (Moll et al., 1992).

Together, these theoretical frameworks guide our use of DMST as a pedagogical and methodological tool for fostering a more inclusive, humanizing mathematics education that prioritizes equity, cultural, and community, while also aligning identity formation with critical digital media production.

Methodology

We used Narrative Inquiry (Clandinin & Connelly, 2000) and Counter-Storytelling (Solorzano & Yosso, 2001) as our main research methodologies, positioning storytelling as a tool for identity construction and resistance against dominant narratives. Narrative Inquiry allows us to explore how teachers and students construct their mathematical identities through personal and community-based stories. Counter-Storytelling, grounded in Critical Race Theory (Ladson-Billings & Tate, 2006), challenges mainstream deficit perspectives and offers a space for marginalized voices to redefine their experiences in mathematics education. Our data sources included storycircle transcripts, digital video artifacts, participant reflections, interviews, and feedback from public screenings. Analysis was conducted using constant comparative and narrative coding methods to trace themes related to identity, resistance, and cultural knowledge.

Case Studies and Findings

Case 1: Indonesia – Teacher Identity and Cultural Mathematics

A week-long DMST workshop in Bandung engaged in-service and pre-service teachers in storytelling around community-based mathematics. Stories evolved from daily practices (e.g., investing, skincare routines) to counter-narratives exploring grief, Quranic numeracy, and professional identity. Post-interviews revealed a shift from procedural to relational teaching. One teacher stated, "I now see math in the emotion of loss," emphasizing the identity-shaping impact. The public screening spurred powerful dialogues around identity, affirming CSP and narrative identity in practice.

Case 2: Vietnam – Data Literacy and Justice through Youth Stories

In Ho Chi Minh City, middle schoolers created digital stories over four weeks. One group analyzed tax burdens across neighborhoods, another documented gender norms through peer surveys. Pre/post reflections showed enhanced agency and digital fluency: "I used to think math was boring; now I use it to speak about fairness," a student wrote. DMST amplified youth voices as critical storytellers, linking Counter-Storytelling to equity and civic awareness.

Case 3: Asian American Diaspora – Challenging Stereotypes

In the U.S., Asian American children (ages 8–12) used DMST to question the 'model minority' myth. Initial stories celebrated cultural numeracy (e.g., Lunar New Year, martial arts patterns), but later shifted to address microaggressions, grief, and identity tension during COVID-19. One child narrated, "People think I'm a math robot—I'm more." DMST enabled identity reclamation and critiqued stereotype-driven positioning, directly reflecting Narrative Identity and Counter-Storytelling frameworks.

Findings and Implications

Across all three enactments detailed above, we found the following findings:

1. Mathematics as Counter-Cultural Practice: Participants recognized and valued mathematical knowledge inherent in their communities, challenging the assumption that mathematics exists solely within school-based curricula.
2. Counter-Storytelling as Narrative Identity: Students and teachers used digital storytelling to frame their mathematical journeys, reinforcing the idea that identity is constructed through storytelling.
3. Critical Digital Media Literacy in Math Education: Engaging with digital tools fostered critical awareness of media, positioning students as creators rather than passive consumers of digital content.

Conclusion and Future Directions

Our work highlights the transformative potential of Digital Mathematics Storytelling in fostering culturally sustaining mathematics education in East Asian and Asian diasporic contexts. Beyond simply offering a new research direction, DMST provides a vision of hope—hope that mathematics education can be freed from the shackles of colonization, that it can be a space where students see themselves reflected in the knowledge they construct. By centering students' lived experiences and

amplifying their voices, using DMST connects to broader movements that reclaiming mathematics education as an emancipatory practice.

Through this work, we position Digital Mathematics Storytelling (DMST) as more than an instructional strategy—it is a transformative practice that affirms identity, promotes cultural equity, and repositions students and teachers as co-constructors of mathematical meaning. By integrating culturally sustaining pedagogy with digital media, DMST bridges formal mathematics with lived realities. Our cases demonstrate that DMST challenges dominant educational structures by centering counter-narratives and affirming marginalized voices in mathematics learning.

Mathematics has long been positioned as an objective and neutral field, yet its history is deeply intertwined with power, colonial legacies, and systems of exclusion. Through DMST, we challenge these structures and advocate for a mathematics education rooted in justice, humanity, and cultural relevance. The stories that emerge from these projects demonstrate that mathematics is not just a set of abstract procedures but a dynamic, lived experience tied to identity, history, and agency.

Through this and future work, we take small but significant steps toward a more just, inclusive, and liberatory vision of mathematics education—one where every student has the right to see themselves as a mathematical thinker, storyteller, and change-maker. As we continue to fight for equity in mathematics education, we offer DMST as a concrete tool that connects personal storytelling, digital creativity, and mathematical thinking in service of justice.

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TSG8-12

CULTIVATING CRITICAL MATHEMATICS CONSCIOUSNESS IN PRE-SERVICE TEACHERS THROUGH DIGITAL RESOURCES AND THE RWC MODEL

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Critical Mathematics Consciousness (CMC) is essential for pre-service mathematics teachers to understand the ethical, communicative, and sociopolitical roles of mathematics. Traditional instruction often limits exposure to real-world issues, whereas digital platforms like websites and YouTube offer rich opportunities for critical engagement. This study integrates digital resources into teacher preparation through the Read-Write-Change (RWC) model to foster CMC. In the Read phase, students analyze sociopolitical issues through digital content to explore how mathematics relates to real-world contexts. In the Write phase, they apply mathematical reasoning to challenge bias and justify fairness using models and statistics. In the Change phase, they use mathematics to address misinformation and advocate for equity. Qualitative analysis of reflective journals revealed that this process supported the development of CMC across all three domains, with ethical awareness emerging most strongly, followed by sociopolitical and communicative awareness.

Keywords: Critical Mathematics Consciousness, Digital resources, Pre-service mathematics teachers, Read-Write-Change

Introduction

Mathematics is often viewed as objective and neutral, yet it is socially, culturally, and politically embedded (Gutstein, 2006). Traditional methods tend to prioritize "dominant mathematics," reinforcing passive learning and overlooking equity and cultural relevance (Gutierrez, 2002; Bukko & Liu, 2021). In contrast, social justice mathematics promotes both technical proficiency and critical awareness. Gutstein (2006) highlights the dual goal of "reading and writing the world with mathematics," enabling students to analyze and act on social injustices.

Pre-service teachers (PSTs) often lack exposure to mathematics as a sociopolitical tool (Myers, 2017). Research has shown that approaches like ethnomathematics (Mania & Alam, 2021) and culturally relevant teaching (Olawale, 2025) can shift these perceptions. Critical Mathematics Consciousness (CMC) has emerged as a vital framework for pre-service mathematics teachers, equipping them with the capacity to understand and address the ethical, communicative, and sociopolitical dimensions inherent in the discipline. In the digital age, tools like YouTube provide access to diverse mathematical narratives (Kellner & Kim, 2010), yet remain underused in teacher training. This study aims to explore the following research question: How does the integration of digital resources within a critical pedagogy RWC influence the development of Critical Mathematics Consciousness (CMC) among pre-service mathematics teachers?

Theoretical Framework: Critical Mathematics Education and RWC

Freire's (1974) critical pedagogy underpins transformative math education by emphasizing dialogue and problem-posing (Freire, 2005). Critical Mathematics Education moves beyond procedural fluency to empower students to challenge injustices, critique economic structures, and engage in ethical mathematical reasoning.

Critical Mathematics Consciousness (CMC), rooted in Freire's critical consciousness, requires not just awareness but active engagement. Kokka (2020) describes CMC as comprising sociopolitical understanding, civic empathy, and agency. Register et al. (2021) further categorize it into three domains: Ethical, Sociopolitical, and Communicative Mathematics Awareness.

The RWC model, based on Gutstein (2006) and extended by Nokkaew and Chuechote (2022), incorporates these domains into a cycle of critical reflection and action:

- **Read:** Examine sociopolitical issues via digital media.
- **Write:** Use mathematics to critique and propose fair solutions.
- **Change:** Share findings through media to promote justice.

Research Methodology

Participants included 62 preservice mathematics teachers (PSTs) in a 15-week university pedagogy course. While proficient in mathematical content, they had limited CMC exposure.

Data was collected from reflective journals developed through the RWC processes. Content and thematic analysis focused on how digital tools supported ethical, sociopolitical, and communicative awareness (Register et al., 2021).

Results

This study investigated how integrating digital resources within the Read-Write-Change (RWC) model fostered Critical Mathematics Consciousness (CMC) among PSTs. The findings were structured around the three RWC phases.

In the Read phase, PSTs used digital media such as YouTube to explore sociocultural mathematical practices—highlighting differences between community-based methods and formal mathematics. In the Write phase, they applied tools like GeoGebra and excel to propose more equitable solutions. In the Change phase, PSTs communicated their analyses and alternatives through videos, infographics, and blog posts, aiming to promote fairness and clarity to a target audience. A summary of how PSTs integrate digital resources in RWC is shown in Table 1.

Table 1. RWC model with digital integration

Phase	Mathematical inquiry	Digital Media Integration	Driving Question
Read (R)	Analyze sociopolitical issues through mathematical lenses, such as wage calculations, pricing strategies and data representation in culture.	Take multiple perspectives of mathematics in cultures from digital media across websites and YouTube.	1. Is it reasonable? 2. Is it truly fair? 3. Who benefits, and who is at a disadvantage?
Write (W)	Construct and communicate mathematical justifications for fairness, using statistics, mathematical modeling, or probability to expose biases.	Develop alternative explanations, models and representations to explain mathematical concepts to clarify fairness/unfairness.	What would be a more just method compared to the current system?
Change (C)	Take actions by clarifying misinformation and advocating for justice using mathematical arguments.	Create YouTube videos, infographics, or blog posts to reveal unfairness and propose alternative ones with awareness of recipient.	1. Do we want to create change? 2. How can we make a difference? 3. How should we communicate with stakeholder?

Figure 1 illustrates one case: a YouTube video used to criticize a local wage calculation method (Read), the creation of alternative models via GeoGebra (Write), and a video comment sharing corrected methods to the villager (Change).

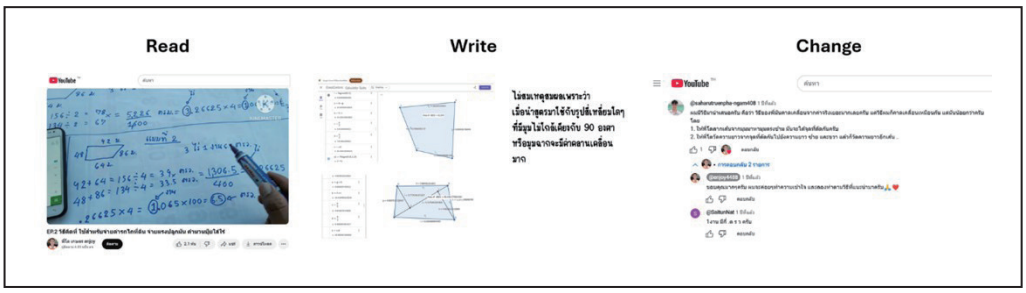

Figure 1. Employing digital resources in RWC pedagogy

Analysis of reflective journals showed that Ethical Mathematics Awareness (E) was most frequently demonstrated (55 out of 62 PSTs), followed by Sociopolitical (P) (35) and Communicative (C) (32). As shown in Figure 2, 27% of PSTs (17 individuals) demonstrated awareness across all three CMC dimensions. Ethical awareness was notably interconnected with both communicative and sociopolitical domains, while the link between the latter two was less evident.

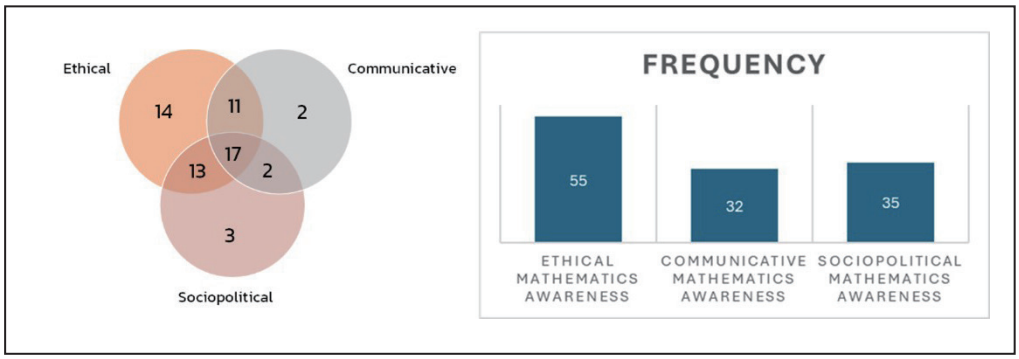

Figure 2. Frequency of awareness in 3 CMC aspects from PSTs' reflective journals

Discussion and Conclusion

The results indicate that the RWC model, supported by digital resources, provided PSTs with authentic opportunities to explore mathematics as a sociopolitical tool. Online platforms such as YouTube serve as accessible and potentially non-hierarchical sources of knowledge, empowering individuals to engage with real-world mathematical problems that illuminate social and economic issues (Kellner & Kim, 2010). These alternative applications of mathematics has the potential to cultivate a more informed citizenry, fostering a critical stance towards the subject (Olawale, 2025). By examining real-world contexts and sharing insights through accessible media, PSTs developed broader perspectives beyond conventional classroom mathematics.

Ethical awareness emerged most strongly, as PSTs recognized the impact of mathematical applications on community well-being and the need to promote accessible, accurate methods. Sociopolitical and communicative awareness followed, highlighting the importance of historical context, usability, and clarity in mathematical communication.

These findings align with Register et al. (2021), who emphasize the role of ethical, sociopolitical, and communicative reasoning in fostering CMC. Despite this progress, the uneven development across domains suggests a need for more balanced and sustained support in mathematics teacher education.

In conclusion, digital integration through RWC offers a promising pathway for cultivating critical mathematics consciousness. Yet, designing meaningful and reflective tasks remains essential for transforming mathematics education into a socially responsive discipline.

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TSG8-13

ETHICAL FOUNDATIONS FOR EXPLORING INCLUSIVE SCIENCE AND MATHEMATICS EDUCATION

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This paper aims to clarify ethical and conceptual foundations in inclusive science and mathematics education, and to identify its elements that develop research and practice. Inclusion itself is a research field that arose from the awareness of social justice ethics. The discussion in this paper begins by considering what it means to be human through disability. As a result, we adopted a political/relational model of disability as the conceptual foundation. In addition, we identified four types of care as elements for developing research and practice: the developmental care, the cognitive care, the epistemological care, and the communal care. We concluded that care ethics is more suitable than traditional ethics as the ethical foundation for developing these elements. We then presented the conceptual foundation, ethical foundation, and elements for developing research and practice of inclusive science and mathematics education as a two-layer model.

Keywords: inclusive science and mathematics education, political/relational model, ethics, care, two-layer model

Introduction

In recent years, the number of studies on special needs education and inclusive education has been increasing in science and mathematics education research all over the world. At the 15th International Congress on Mathematical Education held in Sydney in 2024, Mathematics education for students with special learning needs was set up as a topic study group, and many papers were presented and discussed there. Research on social justice will be positioned as the ethical background of these studies. Research on social justice aims to treat everyone fairly and equitably (Ernest, 2007). In school education, where the diversity of students and school environments is increasing, it is urgent to realize inclusive science and mathematics education that can treat all students fairly and equitably. However, even when reviewing recent research on inclusion, many ideas and concrete examples have been proposed, but not much has been proposed about its foundations and components (e.g., Kollosche et al., 2019). Therefore, the purpose of this paper is to propose the foundations and components of inclusive science and mathematics education (ISME).

Conceptual Foundations of ISME

What causes the difficulty for all students in understanding science and mathematics? This question leads to what it means to be human. When considering what we are as humans, the following three models emerge that capture human beings themselves from the perspective of disability (Lambert,

2019): the individual model of disability, the social model of disability, and the political/relational model of disability. Broadly speaking, these are perspectives on whether the cause of difficulty in understanding science and mathematics is due to the individual learner or to something other than the learner.

When it is believed that the difficulty in understanding science or mathematics is due to the individual learner, the individual model of disability is applied, and medical and neurological research is applied to investigate and treat the causes. From an educational perspective, it is necessary to correct misconceptions about the concepts within the field of science and mathematics. Such misconceptions lead to conceptual change research, a field of study that considers the difficulties in understanding posed by science and mathematics themselves. This epistemological care of the subject will be important. In addition, when looking at learning on a time axis, the developmental care of considering what learning experiences and life experiences individual learners have accumulated before learning, and what existing knowledge and skills they have is also important. And during learning, the cognitive care of what cognitive methods are easy for individual learners to understand will also be important. In the social model of disability, the occurrence of disabilities is considered to be due to the community. In this case, the communal care of how science and mathematics learning are related to the learning community becomes important. This communal care is undertaken by teachers and learners. The teacher's care is to enhance learning activity for all students. The learners inspired by the care provided by the teacher are to foster a caring classroom culture. The political/relational model of disability is a model that arose from the differences between the majority and minority in society, which sometimes involves power (Lambert, 2019). This model argues that the balance of power, human relationships, and invisible cultural beliefs (Lambert, 2019). The social model of disability arose as an antithesis to the individual model, but it has been pointed out that relying solely on the social model of disability creates a dualism regarding the occurrence of disability and hides the physical and medical difficulties of actual disability. Therefore, the political/relational model of disability argues that it is important to consider disability itself while balancing the individual and social models, rather than relying on either one. We propose that the conceptual foundation of inclusive education is the political/relational model of disability. This is because human beings live in a relational web of others and that their identity is strongly influenced by culture and politics. This conceptual foundation is also a philosophical stance that considers what it means to be human from the perspective of disability.

Components of ISME

What factors advance ISME research and practice? It is difficult to present all the important elements for learners to understand science and mathematics, but in a political/relational model, the following four cares can be mentioned: *the developmental care* for the learner before learning, *the cognitive care* for the learner, *the epistemological care* regarding the difficulties inherent in the subject, and *the communal care* that community supports learning.

The developmental care based on developmental psychology may help students understand science and mathematics. Research findings such as those showing the relationship between dexterity and counting, as well as between finger recognition and comparing numbers (Asakawa & Sugimura, 2022), may help identify students who need support in the classroom at an early stage. Providing cognitive care to learners may help them understand science and mathematics. Each individual has their own unique cognitive method, and care that focuses on their uniqueness will be inclusively effective. For example, there is the selection of sequential and simultaneous processing styles in

special needs education research (Fujita, 2019) and research on embodied cognition that makes full use of multimodal stimuli (Abrahamson & Bakker, 2016). Focusing on the difficulty in understanding science and mathematics concepts themselves may help students understand. In mathematics education research, the difficulty in understanding mathematics concepts themselves has been studied as an epistemological obstacle. An epistemological obstacle is a difficulty that arises when previously learned knowledge or skills cause learning difficulties or resistance to new learning, and it is said that this difficulty is not caused by the individual learner, nor is it caused by the instruction (Mizoguchi, 1995). If epistemological care is provided based on such epistemological obstacles, it becomes possible to incorporate mathematical activities that overcome the epistemological obstacles into lesson design in advance. Providing the communal care for the learning community may help students understand science and mathematics. Learning in a caring community allows learners with different perspectives to care for each other and take others' ideas into account (Nishi, 2023). ISME can be thought of as being divided into two layers: the conceptual foundation and its research and practice. The conceptual foundation is the foundation of ISME's philosophy, centered on a fundamental consideration of what it means to be human. The four cares are positioned as elements that develop ISME's research and practice. These two layers influence each other (Kageyama and Matsushima, 2024).

Ethical Foundations of ISME

What are the ethical foundations of ISME? As mentioned above, the inclusive perspective is born out of social justice ethics, which are traditional ethics including Kantian ethics, utilitarianism and rational values (Held, 2015). In mathematics education, the focus is on reading and rewriting the world critically with the goal of learning mathematics for all learners (Gutstein, 2006). In contrast to the traditional ethics of justice, which places emphasis on rights, rules, abstraction, and universalizability, Gilligan (1982) proposed new ethics of care that places emphasis on responsibility to others, relationships, context, and individuality. ISME was enacted to seek better education, so it can be said that the conceptual foundation of ISME is supported by social justice ethics. On the other hand, the elements of ISME are four types of cares. In other words, rather than aiming for the general phenomenon of better education, it can be said that the method and content of ISME aim for the enrichment of individual education using individual relationships inside and outside the classroom. Therefore, it is the care ethics that supports ISME research and practice.

Care ethics was enacted as a challenge to social justice ethics. It is the significance of seeking universality. It is extremely important to seek an ideal environment in which all people are treated equally, but such ideal assumptions inevitably result in people falling outside the scope of those assumptions (Held, 2015). Therefore, care ethics was enacted as a philosophy that is attentive to each individual. This choice was made to ensure that people are not left behind when new goals or methods are introduced and to include all learners. Care is divided into five aspects: Caring about, which is paying attention to what needs are needed; Caring for, which is taking responsibility and consideration to ensure that those needs are met; Care giving, which is actually providing care; Care receiving, which seeks further improvements based on the reactions of the care recipient; and Caring with, which is examining these processes with the members of the community (Tronto, 2013). The last aspect, Caring with, is the very image of democracy in which all members of the community participate. Discussing caring with others and acting on caring creates trust and solidarity in the community. In this way, the experience of expanding solidarity and trust through consensus building based on care ethics leads to ISME for all learners, and this experience is also thought to be connected to the well-being of all human beings.

Considering this, one might think that care ethics is more important than social justice ethics, but this is not the case. Both are important, and it is difficult to strike a balance between them. Issues related to social justice ethics, such as current global environmental issues and war issues, are becoming increasingly complex. To solve these problems, solidarity and trust between us humans are important. At the primary and secondary education stage, it is possible to first place emphasis on care ethics and gradually introduce social justice ethics. The implementation of ISME is the key to our human well-being.

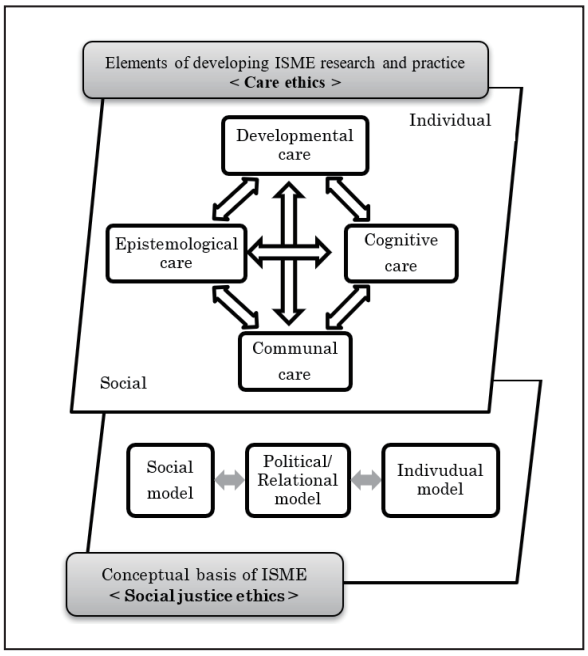

Figure 1. ISME's ethical and conceptual foundations and components

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TSG8-14

NEW POSSIBILITIES FOR PROBLEM FINDING THROUGH MATHEMATICAL MODEL AND CARING

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The present study aims to construct a framework for learning guidance that promotes citizenship through the selection, use, and interpretation of mathematical models, as well as participation in decision-making and consensus-building for social issues. The focus is on the identification of care needs in caring to help learners build relationships with others. This paper demonstrates that the selection, use, and interpretation of mathematical models and the identification of care needs can be done together. To this end, the present study adopted design research as a methodological framework and set learning goals in task design. Using the transition to a joint enrollment system for both genders in Tokyo Metropolitan high school entrance exams as a case study, the present study analyzed the competencies derived from the perspective of how the selection, use, and interpretation of mathematical models contribute to problem findings. The analysis yielded insights into the potential of mathematical models to not only identify individual care needs but also those of the entire group. This analysis consequently led to the formulation of specific learning goals for the task.

Keywords: democracy, care, caring, decision-making, consensus building

Introduction

In a well-functioning democracy, it is essential that all citizens participate in decision making and consensus building on social issues. In mathematics education, social issues have been addressed in the context of expanding mathematical modeling and citizenship education (Abassian et al., 2020; Barbosa, 2006; Geiger et al., 2023). On the other hand, these studies do not necessarily aim at proposing ameliorative measures for social problems or at reaching consensus building based on diverse decisions. Therefore, this study aims to construct a framework for teaching and learning that fosters citizenship that participates in decision-making and consensus building for social problems through the selection, use, and interpretation of mathematical models. On the other hand, in mathematical Science Education that emphasizes learners' values and deals with decision-making and consensus building for social problems through the selection, use, and interpretation of mathematical models, it has been pointed out that the more the issue is a personal matter for the learner, the more differences in values make consensus building difficult (Matsushima et al., 2025). This is because learners do not have sufficient competence to consider the perspectives of others and become fixated on their own values. Therefore, the difficulty of consensus building in previous research is that learners are unable to build relationships with others in finding social problems.

In order to overcome this difficulty, this study focuses on the relationship between the concept of caring and mathematical models, demonstrating the aspects of problem finding in which the selection, use, and interpretation of mathematical models and caring are carried out as a single entity. Caring is the process of identifying diverse care needs, assigning responsibility for meeting those

needs, providing and receiving care, and coordinating which responsibilities are assigned (Tronto, 2015a). From a caring perspective, problem finding in social problems can be interpreted as identifying care needs, and identifying diverse care needs can help overcome the difficulty of consensus building due to adherence to one's values. On the other hand, it is often difficult to identify multiple care needs. Therefore, this study aims to design a task in which the selection, use, and interpretation of a mathematical model and the identification of care needs are performed as a single entity. The purpose of this paper is to argue that the selection, use, and interpretation of a mathematical model and the identification of care needs can be carried out as a single entity.

Methodology

In order to achieve the purpose, this study adopts the methodological framework of design research (Bakker, 2018). Design research focuses on a specific learning content or activity, and aims to develop theories about that learning and its teaching and learning support methods. The design research process typically consists of setting learning goals, designing tasks and teaching practices, and analyzing the practices. In this study, I focus on setting learning goals in this process. In other words, I develop tasks that can be carried out in connection with the selection, use, and interpretation of the identifying for the care needs and the mathematical models, and then I set learning goals for these tasks.

First, under the identifying of care needs, I will review the care process and the ethical elements of that process (Tronto, 2015a; Tronto, 2015b) and theoretically consider the relationship with mathematical modeling competencies (Maass, 2006; Maass et al., 2023) to derive competency rooted in mathematics under the identifying of care needs. Second, I will take the transition from a quota system for boys and girls to a quota system for both genders in the Tokyo Metropolitan high school Entrance Examination as a social issue that requires decision-making and consensus building, and consider how a mathematical model can contribute to problem finding. Third, I will analyze the assumed aspects from the perspective of the derived competency and show that the identification of care needs and the selection, use, and interpretation of mathematical models can be carried out as a single entity, and set the learning goals for the task. Moreover, due to restrictions regarding the available space, the practical application and analysis of the tasks developed will be presented in a separate paper.

Mathematical- Scientific Caring Competencies

This chapter derives competencies rooted in mathematics from the identifying of care needs through theoretical considerations of the relationship between care processes and ethical elements (Tronto, 2015a; Tronto, 2015b) and mathematical modeling competencies (Maass, 2006; Maass et al., 2023).

The Care Process and Ethical Elements

The caring process is a process that aims to identify care needs, take responsibility for resolving those care needs, provide care, interpret whether or not those care needs have been met, and is consistent with a democratic commitment to justice, equality, and freedom for all. The process of identifying care needs is defined as "caring about" (Tronto, 2015a). This process involves not only recognizing that care is needed, but also paying attention to the existence of care needs and valuing them as something that should be met. The ethical elements that correspond to this process is "attentiveness". Although "attentiveness" is something that tries to resist the temptation to ignore or

reject others, we often tend to focus only on ourselves. "Attentiveness" is the competency to "caring about" and can be interpreted as a competency that should be fostered. Therefore, by focusing on mathematics, I will attempt to derive a competency that counteracts the ignorance and rejecting of others and the concern only for oneself that attentiveness points to.

Care Needs Assessment and Mathematical Modelling Skills

Focusing on mathematical modelling competency, I derive the mathematical competency of "caring about". The identification of the care needs corresponds to the process of understanding the problem from a real-world situation and creating a situation model, and simplifying from the situation model to the real model (Maass, 2006) in the mathematical modelling competencies. On the other hand, in mathematical modelling this process takes place in reality, so mathematics cannot help to resist the temptations mentioned above. Therefore, I will focus on the development of mathematical modelling from the perspective of citizenship education in recent years. This points to the importance of competencies based on real-world data, such as gathering information and analyzing sources, as well as simplification, when creating a real model from a situation model (Maass et al., 2023). Therefore, in this study, I will develop competencies that mathematically assess care needs using data and identify new care needs based on the assessment. In this way, I call the competencies for carrying out the care process with a focus on mathematics the mathematical caring competencies and define its sub-competency "caring about" as the identification of unmet care needs in a given society through the selection, use and interpretation of mathematical models using data.

Task Design

In this chapter I will take social issues that require decision making and consensus building and look at the aspects of problem finding that learners can do.

Social Issues that Require Decision-Making and Consensus Building

As a social issue that requires decision-making and consensus building, I will take up the transition from a quota system for boys and girls to a quota system for both genders in the Tokyo Metropolitan high school Entrance Examination. In 2021, it was considered a problem due to the quota system for boys and girls in the Tokyo Metropolitan high school Entrance Examination, even if they had the same score in the entrance examination, boys would pass and girls would fail. The Tokyo Metropolitan Board of Education (hereinafter referred to as the Board) announced its view that if the results of the 2021 entrance examination were determined based on a quota system for both genders, 691 girls and 95 boys would have passed. Therefore, the Board considered establishing a quota system to gradually move from a quota system for each gender to a quota system for both genders and to determine whether or not to admit students based on their exam results regardless of their gender. In this consideration, the Board presented an estimate that the number of girls admitted would increase by approximately 600 and the number of boys admitted would decrease by approximately 600 as a result of the change to a joint quota system for both genders. On the basis of this estimate, the quota for the 2022 admissions was gradually increased to 10% of the quota, the quota for the 2023 admissions was gradually increased to 20% of the quota, and the system was effectively changed to a joint quota system for both genders from the 2024 admissions.

The Aspects of Problem Finding that Learners Can Do

I will focus on the calculations presented by the Board, which show that the number of girls admitted will increase by approximately 600 and the number of boys admitted will decrease by approxi-

mately 600 from the 2021 entrance exam onwards, if a joint quota system for both genders is introduced, and I will examine under what conditions the above increases and decreases could occur. I make the following settings and assumptions.

Setting
C_M…Maximum number of boys, C_F…Maximum number of girls,
S_M…Number of successful boys, S_F…Number of Successful Girls
Assumptions
①The number of successful applicants is equal to the maximum number
②Of the k % of the quota, l % are passed by girls.

The number of successful applicants for each gender in a system with separate quotas for boys and girls is $S_{M1} = C_M$ for boys and $S_{F1} = C_F$ for girls. When the quota is set, the number of successful boys, S_{M2}, and the number of successful girls, S_{F2}, are calculated as follows: $S_{M2} = C_M \times (1 - \frac{k}{100}) + (C_M + C_F) \times \frac{k}{100} \times (1 - \frac{l}{100})$ $S_{F2} = C_F \times (1 - \frac{k}{100}) + (C_M + C_F) \times \frac{k}{100} \times \frac{l}{100}$. If $C_M = 10436$, $C_F = 10010$. I will find the conditions under which the increase in the number of successful girls is consistent with the Board's estimates.

Table 1. Trial estimation results by the board

Year	2021	2022	2023	2024
k	0	10	20	100
Number of girl applicants (persons)	10010	10234	10495	10606
Number of boy applicants (persons)	10436	10212	9951	9840
Number of additional girl applicants who passed (persons)		224	485	596

The case of a joint quota system for both genders is when k = 100, and if the change in the number of additional girls passing the exam in 2021 is represented by y, then $y = -C_F \times \frac{k}{100} + (C_M + C_F) \times \frac{k}{100} \times \frac{l}{100} = -10010 + (10436 + 10010) \times \frac{l}{100}$. If I take $\frac{l}{100}$ as the variable x, then x is the percentage of the number of girls who passed the exam out of the total number of people who took the exam. So I will look at how y changes as x changes. This is to consider the change in the function $y = 20446 \times x - 10010$. If the number of girls admitted to the school increases by 596 in a joint quota system for both genders, the percentage of the number of girls admitted to the school in the quota is calculated. This is to find the value of x that makes $y = 596$. when $y = 596$, $x = 51.873$. Since x is the percentage of girl applicants who passed the exam out of the total number of applicants, it is clear that girl applicants scored higher than boy applicants in the 2021 entrance exam for all Tokyo Metropolitan high schools. Moreover, since the Board's calculations are based on actual data from 2021, which shows the above situation, discussing the transition of the admissions system based on these calculations may confirm the current situation of reluctantly admitting girls with higher scores than boys. In other words, through the use and interpretation of functional models, it is possible to find a problem that requires social decision making and consensus building, such as "How can all genders of examinees be given equal opportunities under any system?"

Discussion

By analyzing the assumed problem finding process from the perspective of "caring about", I will show how the selection, use, and interpretation of mathematical models can be integrated with the identification of care needs and set the learning goals for this task. In this case, there was a girl (boy) who did not pass the entrance examination for a Tokyo Metropolitan high school even though she had a higher score than a boy (girl) who passed. From this, the individual care needs of the examinees, "who should be evaluated equally without regard to gender differences," were identified. Furthermore, the Board has estimated an increase of approximately 600 in the number of female applicants and a decrease of approximately 600 in the number of boys accepted from the 2021 entrance examination onwards. This adjustment is attributed to the transition to a joint quota system for both genders. This determination was made through the utilization and interpretation of a functional model employing current entrance examination data, which revealed that girls were attaining higher grades than boys. This analysis enabled us to identify not only the individual care needs of the examinees that were initially identified through the events, but also the collective care needs of all examinees. The latter finding underscores the principle that "all examinees should have equal examination opportunities." Through the use and interpretation of mathematical models, it was determined that the care needs of individual examinees, initially apparent in social problem situations, could be identified. This finding suggests that it is possible to identify the care needs of the entire group, which go beyond the care needs of individuals. Consequently, this teaching material contributes to the development of "caring about" in the mathematical caring competency. Therefore, the learning goal of this task can be set as identifying the care needs of all examinees by using and interpreting a function model. This will be done using past entrance examination data to meet the conditions of existing calculations for the Tokyo Metropolitan high school Entrance Examination.

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