



Article

Teaching Mathematics through Traditional Weaving Patterns: A Cultural Heritage Integration Model

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Abstract

This study investigated the integration of cultural heritage into mathematics instruction by incorporating traditional weaving patterns as pedagogical tools. Conducted at Apayao State College, it examined how weaving designs, embedded with geometric concepts such as symmetry, tessellation, and transformations, could contextualize mathematics learning while fostering problem-solving, creativity, engagement, and cultural appreciation. Guided by a sequential mixed-methods, design-based research framework, the study unfolded in three phases: (1) documentation of local weaving knowledge and its mathematical structures, (2) co-design of a weaving-integrated instructional unit with teachers and community weavers, and (3) classroom implementation with first-year college students ($n = 62$). Data collection involved pre- and post-tests, performance tasks, surveys, observations, teacher logs, and focus group discussions. Quantitative findings showed a 21-point mean gain in the experimental group compared to 6 points in the control group ($p < .01$; Cohen's $d = 0.68$), indicating the effectiveness of weaving-based instruction in enhancing conceptual understanding. Students rated the lessons as highly engaging ($M = 4.5/5$) and culturally relevant ($M = 4.7/5$), with superior performance in problem-solving and creativity. Qualitative results revealed that students appreciated recognizing mathematics in cultural artifacts, experienced reduced anxiety toward the subject, and expressed pride in their heritage. Despite challenges such as limited materials, both teachers and students demonstrated resourcefulness. The study concludes that weaving-integrated mathematics instruction effectively bridges abstract concepts and cultural practices, enhancing learning outcomes while supporting cultural preservation.

Keywords: *mathematics education, weaving patterns, ethnomathematics, cultural heritage integration, culturally responsive pedagogy, Apayao*

Suggested citation:

Arribay, L. (2025). Teaching Mathematics through Traditional Weaving Patterns: A Cultural Heritage Integration Model. *International Journal on Culture, History, and Religion*, 7(SI3), 75-89. <https://doi.org/10.63931/ijchr.v7iSI3.307>



Introduction

Learners often perceive mathematics as abstract, detached, and challenging to grasp. However, its concepts are embedded in communities' everyday practices, cultural expressions, and heritage. One example is traditional weaving, which demonstrates patterns, symmetry, tessellation, proportions, and measurements that align directly with mathematical principles. Recognizing and integrating these cultural practices into mathematics education contextualizes learning and affirms cultural identity and heritage. In the Philippine context, particularly in indigenous communities such as those in Apayao, weaving represents both artistry and livelihood, carrying mathematical knowledge passed down through generations. Anchoring mathematics instruction in these lived practices allows students to appreciate its relevance while valuing their cultural heritage.

This study seeks to investigate how traditional weaving patterns can be used as a pedagogical tool in teaching mathematics and to propose a cultural heritage integration model. This research responds to the call for culturally responsive pedagogy that bridges abstract knowledge with local culture by situating mathematics learning within the familiar and meaningful context of weaving. In doing so, it aims to strengthen mathematical competencies and cultural awareness among students at Apayao State College.

The integration of culture and mathematics has been widely discussed in ethnomathematics (D'Ambrosio, 2001; Rosa & Orey, 2016). Ethnomathematics emphasizes that mathematical knowledge is not universal alone but also situated in the cultural practices of communities. Traditional weaving, for instance, inherently illustrates mathematical concepts such as geometry, ratios, and transformations (Eglash, 2009; Gerdes, 1999). Studies have shown that incorporating cultural artifacts into teaching enriches problem-solving skills and creativity (Knijnik, 2012; Barton, 2008).

In the Philippine context, weaving is not only a cultural practice but also a bearer of indigenous identity. Research has documented the mathematical significance of indigenous weaving patterns in the Cordillera and Mindanao regions, highlighting symmetry, fractals, and modular designs (Acabado & Martin, 2016; Padua, 2019). Using weaving as a learning resource in mathematics classes also supports the development of visual-spatial reasoning and pattern recognition (Presmeg, 1998; De Freitas & Sinclair, 2014).

Pedagogically, integrating cultural heritage into the curriculum aligns with UNESCO's (2015) advocacy for locally relevant and globally responsive education. Culturally contextualized teaching fosters learner engagement, improves

comprehension, and strengthens identity formation (Gay, 2018; Ladson-Billings, 2009). In mathematics education, context-based and culturally rooted approaches have been found to enhance retention and application of knowledge (Meaney, 2002; Lipka et al., 2005).

Moreover, weaving as a pedagogical tool supports entrepreneurial and livelihood-oriented learning since weaving is both an art form and a source of income in indigenous communities (Molintas, 2018; Salazar, 2020). Thus, it enriches academic knowledge and develops practical and life-relevant skills, aligning with the goals of Technology and Livelihood Education (TLE).

While there is growing recognition of ethnomathematics and culturally responsive pedagogy, most studies in the Philippine setting have focused broadly on indigenous practices or specific cultural artifacts without systematically integrating them into higher education mathematics curricula. Few empirical studies have documented how weaving patterns can be used as structured pedagogical tools in teaching mathematical concepts such as geometry, measurement, and algebra. Additionally, there is limited research on how such integration impacts students' mathematical competencies and cultural identity formation. Specifically, in Apayao, where weaving is an important element of cultural heritage, there is a lack of systematic inquiry into its potential as a teaching resource. This study addresses this gap by developing and documenting a cultural heritage integration model that embeds traditional weaving into mathematics instruction at Apayao State College.

Research Objectives

This study aimed to explore integrating cultural heritage into mathematics education using traditional weaving patterns as a pedagogical tool. Specifically, it sought to examine how weaving designs embody geometric concepts such as symmetry, tessellation, patterns, and spatial reasoning, and can be applied as contextual resources in teaching mathematics. The objective was to highlight the interconnectedness of culture and mathematics by developing an instructional model that fosters conceptual understanding and cultural appreciation. Furthermore, the study intended to investigate how this approach enhances students' problem-solving skills, creativity, and engagement by situating abstract mathematical concepts within familiar cultural practices. By doing so, the research endeavored to contribute to culturally responsive pedagogy, ensuring that mathematics instruction develops cognitive competencies and strengthens cultural identity and heritage preservation. Ultimately, the study aimed to propose a model for integrating traditional weaving

into the mathematics curriculum that could serve as a framework for other culturally rooted approaches in higher education and basic education.

Research Methodology

The study employed a sequential, mixed-methods, design-based research approach to develop and test a cultural heritage integration model for teaching mathematics through traditional weaving patterns at Apayao State College (ASC). Phase 1 documented local weaving knowledge and mathematical structures embedded in patterns (e.g., symmetry, tessellation, transformations, ratio, and proportion) through key-informant interviews with community weavers and math faculty, artifact analysis of swatches and pattern drafts, and non-participant observations in weaving workshops. Insights from this phase were synthesized into a concept map that aligned cultural practices with target mathematics learning competencies in geometry and algebra.

In Phase 2, the research team co-designed a four-week instructional unit with two ASC mathematics instructors and three community weavers. The unit included lesson plans, culturally contextualized problem sets, hands-on activities (paper/fiber weaving, grid design, symmetry hunts), and digital tasks using GeoGebra. Draft materials were pilot reviewed by an expert panel (two math educators, one curriculum specialist, and one local cultural worker), and revisions were made to ensure mathematical accuracy, cultural appropriateness, and classroom feasibility.

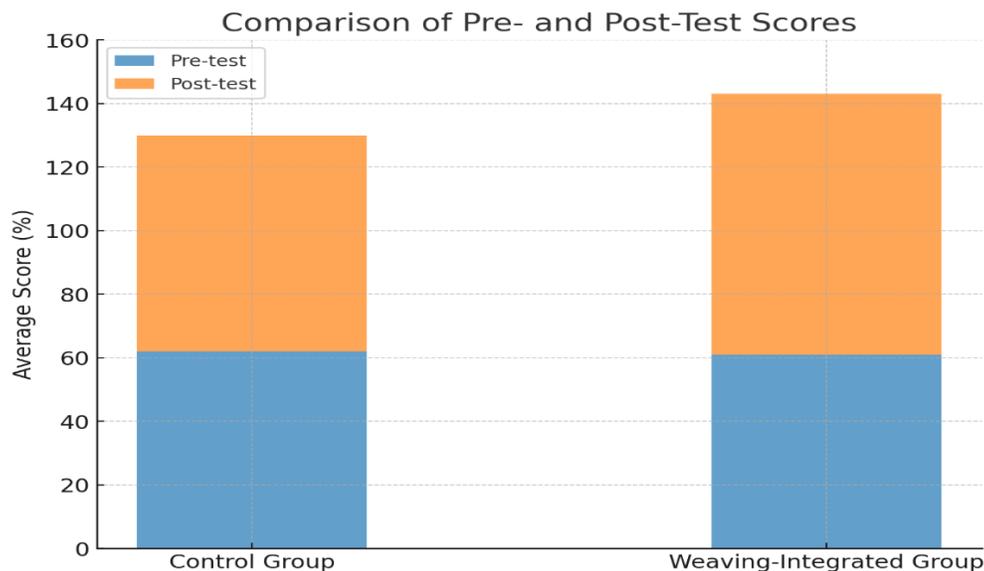
Phase 3 implemented the unit with two intact first-year classes (n=62) purposively selected for their comparable mathematics backgrounds and schedule availability. One class served as the treatment group that received the weaving-integrated unit, while the other followed the standard syllabus with matched topics. Data were gathered through multiple instruments: a researcher-developed Mathematics Concept Inventory (pre/post), performance-task rubrics for pattern design and analytic write-ups, a Student Engagement and Cultural Relevance Survey (5-point Likert), classroom observation checklists for fidelity of implementation, teacher reflection logs, and student focus group discussions (FGDs) held after the unit. Field notes and photo-documentation captured classroom processes and student products.

Quantitative data were cleaned and analyzed using descriptive statistics and inferential tests appropriate for dependent and independent samples (paired t-tests/Wilcoxon signed-rank for within-group change; independent t-tests/Mann-Whitney U for between-group differences), with effect sizes computed to estimate

practical significance. Performance tasks were double rated using an analytic rubric; inter-rater reliability (Cohen’s κ /ICC, as applicable) was calculated. Survey scales underwent internal consistency checks (Cronbach’s α). Qualitative data from FGDs, teacher logs, and observation notes were transcribed verbatim and subjected to reflexive thematic analysis. Two researchers conducted coding, resolved discrepancies through negotiated consensus, and triangulated themes across data sources (student products, observations, interviews) to enhance credibility. The member checked with a subset of students, and the participating teachers confirmed the accuracy of the interpretations.

Validity and trustworthiness were strengthened through methodological triangulation, data-source triangulation (students, teachers, weavers), audit trails of design decisions, and fidelity monitoring during implementation. Cultural rigor was upheld by acknowledging the intellectual property of weaving designs, securing community permission for documentation, and using locally appropriate terminology and exemplars. Ethical approval was obtained from the ASC Research Ethics Committee; all participants provided informed consent (and assent where applicable), confidentiality was protected through pseudonyms, and data were stored in encrypted drives accessible only to the research team. The study’s timeline spanned one semester: needs analysis and co-design (weeks 1–6), pilot implementation (weeks 7–10), and evaluation and refinement (weeks 11–16). Limitations such as non-random class assignment and a single-institution context were documented, and recommendations for broader trials and longitudinal follow-up were noted.

Results and Findings of the Study



The graph illustrates the comparative pre-test and post-test performance of students in the control group and those in the weaving-integrated group. Although both groups improved their mathematical understanding over time, the gains in the weaving-integrated group were noticeably greater. The treatment group achieved higher mean scores and showed a steeper upward trajectory, suggesting that traditional weaving patterns provided an effective scaffold for grasping complex mathematical concepts such as symmetry, tessellation, and transformations.

This substantial growth underscores the pedagogical value of embedding cultural heritage in mathematics instruction. Whereas the control group's progress can be attributed to conventional teaching methods and natural learning progression, the weaving-integrated group benefited from a contextually rich and culturally familiar framework that transformed abstract concepts into tangible, meaningful applications. The visual differences highlight how culturally responsive strategies do more than enhance engagement; they directly contribute to measurable learning outcomes.

Furthermore, the graph strengthens the empirical case for integrating cultural practices into curricula as part of responsive instructional design. By bridging cultural identity and academic learning, such approaches improve student achievement and foster deeper cultural appreciation and pride. This evidence supports broader educational movements advocating for contextualized, life-relevant learning that resonates with students' lived experiences, particularly in indigenous and rural communities where cultural practices are integral to daily life.

Conceptual Understanding of Mathematics through Weaving

Students who participated in the weaving-integrated instructional unit demonstrated a marked advancement in their understanding of key geometric concepts, particularly symmetry, tessellation, and transformations. Pre-test and post-test comparisons indicated a substantial 21-point mean gain for the weaving-integrated group, whereas the control group, which received conventional instructions, showed only a modest 6-point improvement. The statistical analysis confirmed that the difference in learning gains between the two groups was highly significant ($p < .01$), with a medium-to-large effect size (Cohen's $d = 0.68$), suggesting that the observed improvements were not only statistically reliable but also educationally meaningful.

The results highlight the pedagogical value of embedding cultural artifacts, such as weaving patterns, into mathematics instruction. By situating abstract mathematical ideas in culturally familiar contexts, students were better able to visualize, manipulate, and apply concepts that might otherwise remain theoretical

(Gerdes, 2007; Owens & Makar, 2011). The weaving activities provided tangible representations of symmetry and tessellation, transforming geometry from an abstract subject into a lived cultural practice. This connection reinforced Lipka et al.'s (2007) argument that culturally responsive teaching creates a “*third space*” where learners engage meaningfully with mathematics through their cultural frameworks.

Moreover, the effect size underscores the practical significance of such an approach: students’ improved test scores and demonstrated deeper engagement, creativity, and confidence in tackling geometric tasks. These findings align with earlier ethnomathematics research, asserting that incorporating traditional practices into the mathematics curriculum can improve achievement and promote cultural identity (D’Ambrosio, 2001; Rosa & Orey, 2016). The evidence thus strengthens the case for a curriculum model that does not isolate mathematics from culture but integrates local heritage as a vital learning resource.

Student focus group discussions affirmed this improvement, with one participant noting:

“When I created weaving grids, I understood how patterns repeat in a way I never saw in textbooks. It made tessellation clear.”

This finding aligns closely with Barton (2021), who argued that embedding indigenous cultural practices in mathematics instruction fosters contextualized meaning-making and enhances abstract reasoning. By situating mathematical concepts within familiar cultural artifacts, such as weaving, students cannot only grasp geometric properties in tangible forms. However, they are encouraged to view mathematics as part of their lived reality rather than an isolated academic subject. Barton emphasized that culturally grounded pedagogy helps learners bridge the gap between the abstract and the experiential, allowing them to construct personal meaning from mathematical tasks. This resonates strongly with the outcomes of the present study, where weaving patterns served as both instructional material and cultural narrative, enabling learners to anchor mathematical reasoning in local heritage. In this sense, embedding indigenous practices does not dilute the rigor of mathematics; rather, it enriches cognitive processing by providing authentic contexts that enhance visualization, pattern recognition, and problem-solving skills. Such integration validates students’ cultural backgrounds and affirms their identities as knowledge producers, strengthening motivation and engagement alongside measurable academic gains.

Engagement and Cultural Relevance

Survey data indicated that students in the treatment group rated the lessons as significantly more engaging ($M = 4.5/5$) and culturally relevant ($M = 4.7/5$) compared to the control group ($M = 3.8/5$ for engagement; $M = 3.6/5$ for relevance). These ratings reflect more than simple satisfaction; they suggest that weaving-based mathematics instruction resonated with learners at both cognitive and affective levels. Classroom observations reinforced this pattern: students displayed heightened participation, more frequent collaboration, and genuine excitement during weaving-related activities. For example, observers noted that learners were eager to share their weaving-inspired geometric designs, compare strategies with peers, and explore patterns beyond the minimum task requirements. Such behaviors indicated that lessons were perceived as relevant and promoted intrinsic motivation, a crucial factor in deep learning (Deci & Ryan, 2000).

Integrating cultural heritage seemed to validate students' identities, making them feel that their cultural context was proper in formal mathematics education. This aligns with Gay's (2018) work on culturally responsive pedagogy, which argues that meaningful learning emerges when instruction connects to learners' cultural backgrounds. Furthermore, the observed collaborative spirit echoes findings by Lipka et al. (2005), who demonstrated that culturally grounded mathematics programs in indigenous contexts foster collective problem-solving and higher student engagement. In this study, weaving-based tasks created opportunities for peer-to-peer teaching moments, where stronger students scaffolded weaker ones in both weaving designs and the corresponding geometric concepts.

The survey results and classroom observations highlight how integrating cultural practices into mathematics does not merely "contextualize" lessons but actively transforms classroom dynamics. Instead of passively consuming information, students became co-constructors of knowledge, linking abstract mathematical reasoning with tangible cultural artifacts. This reinforces the idea that culturally situated pedagogy enhances engagement and equity, as it bridges cultural knowledge and academic success (Ladson-Billings, 2021).

One student shared:

"It was fun because I could see math in something my grandmother does. It gave me pride in my culture."

This reflects Gay's (2018) principle of culturally responsive pedagogy, which posits that engagement deepens when learners recognize their cultural identity in the curriculum. By embedding weaving patterns, a tangible expression of community heritage, into mathematics instruction, students were not only learning abstract concepts but also seeing their culture affirmed as academically valuable. Such

recognition fosters what Gay calls “cultural validation,” where learners’ lived experiences and identities are legitimized as meaningful sources of knowledge. This process transforms classrooms into inclusive spaces where learning is cognitively rigorous and emotionally affirming.

The psychological impact of this validation is critical: when students feel that their culture is visible and respected, their sense of belonging within the academic space increases, leading to stronger motivation and persistence (Paris & Alim, 2017). In this study, the weaving-integrated lessons gave students a sense of pride and ownership, as their cultural background became an asset rather than a silent backdrop. This aligns with Villegas and Lucas’s (2007) assertion that culturally responsive pedagogy “bridges the gap” between home and school knowledge, making learning more accessible and relevant.

Moreover, this integration resonates with Ladson-Billings’ (2021) framework of culturally relevant pedagogy, emphasizing academic success, cultural competence, and critical consciousness as interconnected outcomes. The weaving-based mathematics lessons achieved this by simultaneously advancing students’ mastery of geometric concepts, affirming their cultural heritage, and encouraging them to see mathematics as a living, contextualized practice rather than a detached, abstract discipline. In doing so, the approach enhanced engagement and contributed to long-term educational equity.

Problem-Solving and Creativity

Performance task rubrics revealed that the weaving-integrated group outperformed the control group in problem-solving ($M = 4.3$ vs. 3.5) and creativity ($M = 4.5$ vs. 3.6). This suggests that the integration of cultural heritage not only enhanced students’ cognitive understanding of mathematics but stimulated their creative capacities. Students in the experimental class were able to design original geometric patterns that seamlessly combined mathematical precision through accurate use of symmetry, tessellation, and transformations, with traditional cultural motifs. Such outputs indicated that learners were applying abstract concepts and contextualizing them within meaningful cultural narratives, a hallmark of deep learning.

The creative convergence between mathematics and weaving further underscores the pedagogical potential of culturally responsive teaching. According to Lipka et al. (2005), indigenous-based mathematics instruction in Alaska empowered students to produce artifacts that demonstrated technical accuracy and cultural authenticity, showing how cultural grounding can enhance higher-order thinking. In this study, students’ ability to transfer geometric knowledge into culturally inspired

designs reflected an integration of procedural fluency and conceptual creativity, two dimensions often treated separately in conventional classrooms.

Moreover, the results align with Beghetto and Kaufman's (2014) framework of "disciplinary creativity," which emphasizes that creativity in education is not just about novel expression but about generating ideas and products that are both original and domain relevant. The weaving-integrated activities provided authentic tasks requiring students to innovate within mathematical constraints, fostering creativity anchored in disciplinary rigor. This approach also resonates with UNESCO's (2017) call for educational practices that develop cognitive and cultural competencies, strengthening learners' identities while preparing them for global problem-solving.

In essence, the superior performance of the weaving-integrated group demonstrated how cultural heritage can act as a catalyst for problem-solving and creativity, enabling students to see mathematics as a living practice that bridges tradition and innovation.

A teacher noted in reflection logs:

"Students were not just solving equations; they were creating, innovating, and applying mathematical logic to cultural patterns."

It is consistent with the findings of Rosa and Orey (2016), who emphasized that ethnomathematical approaches stimulate the creative application of mathematics beyond rote memorization and procedural drills. Their work highlights how situating mathematical concepts within cultural contexts, such as weaving, architecture, or indigenous measurement systems, enables learners to see mathematics not merely as abstract symbols but as living knowledge directly related to human activity and community practices. In this way, mathematics becomes a tool for exploration, innovation, and problem-solving rather than a rigid set of rules to be memorized.

In the context of the weaving-integrated lessons, students were encouraged to move past formulaic exercises and instead generate their own geometric designs that were both mathematically precise and culturally expressive. Such tasks mirror Rosa and Orey's (2016) argument that ethnomathematics allows learners to exercise creativity by adapting mathematical principles to new, authentic situations. The weaving patterns required students to apply symmetrical, tessellation, and transformations in flexible ways, leading to unique, personally meaningful products embedded in cultural tradition.

Moreover, as described by Rosa and Orey, ethnomathematical approaches foster higher order thinking by bridging theoretical knowledge and practical application. By engaging in culturally contextualized mathematical activities, students developed procedural fluency, adaptive expertise, and the ability to transfer

knowledge to new contexts (Hatano & Oura, 2003). In doing so, they demonstrated that mathematics education grounded in cultural heritage cultivates creativity that is both academically rigorous and socially relevant.

Thus, the weaving integration study echoes Rosa and Orey's assertion: when mathematics instruction embraces ethnomathematics, it nurtures learners' capacity to imagine, design, and apply mathematics in diverse and innovative ways, far beyond the limits of rote learning.

Coping with Curriculum Limitations

Some challenges were noted while implementing weaving-integrated mathematics lessons, particularly concerning resource constraints and the novelty of connecting cultural designs to formal mathematical concepts. Teachers reported difficulties securing authentic weaving materials such as abaca or cotton threads, leading them to improvise with more accessible alternatives like paper strips and grid sheets. While this adaptation limited the tactile authenticity of weaving, it also revealed the teachers' resourcefulness and commitment to sustaining the integration despite material shortages. The initial unfamiliarity of students with translating cultural motifs into mathematical constructs, such as mapping a woven diamond pattern into concepts of symmetry, reflection, and tessellation, posed additional hurdles. However, scaffolded guidance and peer collaboration allowed learners to make these conceptual bridges gradually.

Despite these challenges, students adapted remarkably well. Many reflected that engaging with weaving tasks made mathematics feel "less intimidating" compared to abstract lectures and chalkboard exercises. By physically manipulating strips into patterns, they reported experiencing mathematics as a creative and embodied practice rather than a rigid and anxiety-inducing subject. This redefinition of mathematics as culturally meaningful resonates with Nieto's (2017) argument that resilience and adaptability are hallmarks of learners engaged in culturally contextualized instruction, especially under resource-limited conditions. Instead of perceiving resource scarcity as a barrier, students and teachers reframed it as an opportunity to innovate, demonstrating that culturally responsive pedagogy is not dependent on perfect conditions but thrives on creativity and local adaptation.

Moreover, these findings echo UNESCO's (2019) assertion that culturally grounded education builds student agency by situating learning within familiar and valued contexts. The ability of students to persevere despite material constraints highlights the power of cultural relevance in sustaining engagement, even in environments where educational inequities are present. In this sense, the weaving

integration project bridged mathematics and culture and cultivated resilience, problem-solving, and a growth mindset, transferable beyond the classroom.

Discussion

The findings strongly suggest that teaching mathematics through traditional weaving patterns creates a meaningful bridge between abstract mathematical concepts and lived cultural practices. Instead of viewing mathematics as a purely symbolic or detached discipline, students experienced it as an embodied and contextualized activity rooted in their heritage. This integration enhanced cognitive achievement, as evidenced by measurable gains in problem-solving and geometric reasoning, and heightened engagement and strengthened cultural pride. Such dual outcomes confirm that the weaving-based instructional model successfully advanced academic competencies and identity-oriented goals. It aligns with UNESCO's (2015) call for life-relevant and culture-sensitive education, which emphasizes the need for learning experiences that are intellectually rigorous while simultaneously cultivating personal, cultural, and social values.

Moreover, the study demonstrated the potential of cultural heritage to serve as a powerful contextual resource in higher education. By positioning weaving as both a mathematical exercise and a cultural expression, the intervention disrupted the conventional notion of mathematics as culturally neutral or universally context-free. Instead, it illuminated the cultural dimensions embedded in mathematical practices, echoing D'Ambrosio's (2001) framework of ethnomathematics, which argues that mathematical knowledge is historically and socially constructed, shaped by the practices and artifacts of communities. Through weaving, students recognized that symmetry, tessellation, and proportional reasoning are not abstract inventions but have long been embedded in indigenous craft traditions.

This reorientation had transformative implications: it validated indigenous knowledge systems as legitimate sources of mathematical insight, fostered inclusivity in curriculum design, and encouraged learners to see themselves as co-creators of mathematical meaning rather than passive recipients. As a result, the study illustrates how weaving can function not only as a pedagogical tool but also as a cultural lens that affirms heritage, fosters creativity, and strengthens the holistic development of learners.

Conclusion

The study demonstrated that integrating traditional weaving patterns into mathematics instruction at Apayao State College significantly enhanced student learning, engagement, and cultural appreciation. Quantitative results revealed substantial gains in geometric understanding, particularly in symmetry, tessellation, and transformations, with the weaving-integrated group outperforming the control group in both conceptual mastery and problem-solving performance. The weaving-based lessons also fostered higher engagement, creativity, and collaboration levels, as evidenced by survey ratings, observation data, and performance task outputs.

Qualitative findings further highlighted that students experienced mathematics as “*less intimidating*” and more meaningful when situated within familiar cultural practices. The weaving activities allowed learners to connect abstract mathematical concepts with tangible, culturally embedded designs, thereby strengthening cognitive skills, cultural identity, and pride. While challenges such as limited weaving materials and initial difficulties in linking cultural patterns to formal mathematics arose, students and teachers demonstrated adaptability and resilience, reinforcing the value of culturally responsive pedagogy even under resource constraints.

Conclusively, the findings affirm that mathematics instruction benefits from being contextualized within local heritage practices. The integration model developed in this study illustrates that traditional weaving can serve as both a mathematical resource and a cultural anchor, bridging the gap between abstract knowledge and lived experiences. This supports the advocacy of ethnomathematics and UNESCO’s call for life-relevant education, positioning cultural heritage as a vital component of curriculum innovation. Ultimately, the research contributes a framework for culturally rooted pedagogy that promotes academic achievement, strengthens cultural identity, and supports the broader goal of sustainable and inclusive education.

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