

Integrating Ethnomathematics into the Quantum Learning Model to Support Mathematics Learning and Quality Education

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Abstract: This study aims to describe how the quantum learning model and ethnomathematics have been examined in recent research and to examine whether and how the two approaches can be combined to support elementary mathematics learning and quality education. The study extends previous research, which has largely examined each approach separately, by analysing quantum learning and ethnomathematics together within the context of elementary mathematics learning and by relating them explicitly to SDG 4. A qualitative descriptive design was used, combining a literature corpus (56 articles screened, 28 included), semi-structured teacher interviews, and documentation. Data were analysed through data reduction, data display, and conclusion drawing. Half of the included articles were published in 2024, and the articles were distributed across ethnomathematics ($n = 15$), quantum learning ($n = 9$), and SDG 4 ($n = 4$). The Scopus-indexed studies summarised here report positive outcomes of quantum learning for achievement, retention, critical thinking, and collaboration, and positive but variable outcomes of ethnomathematics for mathematical learning. A conceptual alignment between the six phases of quantum learning and ethnomathematics-based activities is proposed for empirical testing in elementary classrooms.

Keywords: Quantum Learning; Ethnomathematics; Elementary Mathematics Education; Quality Education; Qualitative Descriptive Study.

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INTRODUCTION

Quality education is central to the Sustainable Development Goals (SDGs), particularly SDG 4. In Indonesia, SDG 4 accounted for four of the twelve priority indicators identified through provincial-level correlation and network analysis (Rimba et al., 2025). Evidence from Malaysia, Indonesia, and Pakistan also indicates a positive association between school enrolment and sustainable development (Khan et al., 2024).

School closures during the COVID-19 pandemic raised concerns about learning quality. In the Netherlands, primary students made little or no progress during home learning, with losses of approximately 0.08 standard deviations and larger losses among students from less-educated households (Engzell et al., 2021). An early systematic review synthesised evidence of pandemic-related learning loss (Donnelly & Patrinos, 2022), while a meta-analysis of 42 studies across 15 countries found an overall learning deficit (Cohen's $d = -0.14$), with larger deficits in mathematics than in reading and in middle-income than in high-income countries (Betthäuser et al., 2023). Subsequent research has examined learning recovery measures (Dela Cruz et al., 2025). This evidence provides context for the difficulties with basic arithmetic operations reported by the teacher interviewed in the present study.

Teaching approaches influence students' engagement with mathematics. Khozaei et al. (2022) described limitations of lecture-based instruction, including student inactivity and rapid forgetting, and examined the quantum learning model as an interactive alternative. The model comprises six phases: *enroll*, *experience*, *label*, *demonstrate*, *review*, and *celebrate*. In Indonesia, these phases are commonly operationalised as TANDUR: *Tumbuhkan (Enroll)*, *Alami (Experience)*, *Namai (Label)*, *Demonstrasikan (Demonstrate)*, *Ulangi (Review)*, dan *Rayakan (Celebrate)*.

Previous studies have reported positive outcomes of quantum learning across several contexts. Khozaei et al. (2022) found higher achievement and retention among nursing students in Iran than among those receiving lecture-based instruction. Nahar et al. (2022) reported improved collaborative thinking in elementary Islamic religious education, while Şahin and Kılıç (2024) found improvements in critical thinking following problem-based quantum learning.

Ethnomathematics connects mathematics with cultural practices and real-world contexts (Aprinastuti & Amelia, 2025). A meta-analysis reported a strong effect of

ethnomathematics-based learning on mathematical literacy (Pratama & Yelken, 2024), while a randomised evaluation in Panama found improvements in preschool children's mathematical and ethnomathematical skills (Näslund-Hadley et al., 2025). Other studies have examined junior high school teachers' beliefs about ethnomathematics-based numeracy learning (Astuti et al., 2024) and Indonesian and Thai educators' perspectives on its significance (Payadnya et al., 2024).

Existing studies have primarily examined quantum learning and ethnomathematics separately. The quantum learning studies discussed above were conducted in nursing education, Islamic religious education, and critical thinking contexts, and none of them addressed elementary mathematics. The ethnomathematics studies discussed above were concentrated in preschool, junior high school, and teacher education contexts. Research remains limited regarding how quantum learning and ethnomathematics can be combined for elementary mathematics learning and how such a combination relates to SDG 4.

This study aims to examine whether and how the quantum learning model and ethnomathematics can be combined to support elementary mathematics learning and quality education (SDG 4), guided by three research questions: (1) What are the characteristics and main findings of recent literature on the quantum learning model, ethnomathematics, and SDG 4? (2) How does an elementary school teacher describe students' difficulties in learning basic mathematics after remote learning? and (3) How can the phases of quantum learning be aligned with ethnomathematics-based activities to support elementary mathematics learning and SDG 4?

METHODS

Research design

This study employed a qualitative descriptive design to examine published research, describe a teacher's account of students' mathematics difficulties, and develop a conceptual alignment between quantum learning and ethnomathematics. The study describes existing evidence without manipulating instructional conditions or evaluating an intervention.

Data sources and participant

Data sources comprised a literature corpus, a semi-structured interview, and supporting documentation. The literature informed RQ 1 and RQ 3, while the interview addressed

RQ 2. The interview involved one sixth-grade elementary school teacher in Surabaya, Indonesia, identified as Teacher 1. Documentation of ethnomathematics integration provided contextual information and was not analysed as a separate dataset.

Literature corpus and screening

The literature corpus covered quantum learning, ethnomathematics, and SDG 4. Of the 56 articles screened, those addressing at least one theme and published in SINTA-accredited national journals or Scopus-indexed international journals were retained. Each included article was coded by theme, publication year, source type, and research method. The Results section cites Scopus-indexed studies for the thematic synthesis.

Interview procedure

A semi-structured interview explored the planning, implementation, and outcomes of mathematics learning models, allowing the teacher to describe students' difficulties in her own words. Responses relevant to RQ 2 were summarised descriptively, and the teacher's identity and school name were anonymised.

Data analysis

Data analysis comprised data reduction, data display, and conclusion drawing. Relevant information was selected and organised into tables and descriptive summaries. Articles were grouped thematically following the general logic of thematic analysis (Braun & Clarke, 2006). The phases of quantum learning described by Khozaei et al. (2022) were then compared with ethnomathematics-based activities to develop the conceptual alignment for RQ 3.

Research quality and limits of the data

Interpretations were compared across the literature, interview, and supporting documentation. Claims were restricted to the available evidence. The study involved one teacher, and the included articles were not subjected to formal quality appraisal. These limitations inform the interpretation of the findings.

RESULTS

RQ 1: Characteristics of the reviewed literature

RQ 1 asks about the characteristics and main findings of recent literature. This subsection first reports the composition of the corpus, because the composition shows what kinds of evidence the later synthesis can draw on. Table 1 presents the screening outcome, the

thematic distribution, and the source types of the included articles. The table is included so that readers can judge the balance between themes and between national and international sources.

Table 1. Screening outcome and composition of the corpus

Aspect	Category	n	%
Screening	Articles screened	56	100.0
Screening	Articles included	28	50.0
Theme (of included articles)	Ethnomathematics	15	53.6
Theme (of included articles)	Quantum learning	9	32.1
Theme (of included articles)	SDG 4	4	14.3
Source type (of included articles)	SINTA-accredited national journals	11	39.3
Source type (of included articles)	Scopus-indexed international journals	17	60.7

Of the 56 screened articles, 28 met the inclusion criteria. Ethnomathematics accounted for 15 articles (53.6%), quantum learning for nine (32.1%), and SDG 4 for four (14.3%). Seventeen articles (60.7%) were published in Scopus-indexed international journals, while 11 (39.3%) appeared in SINTA-accredited national journals. The corpus included qualitative and quantitative studies, meta-analyses, and systematic reviews; therefore, the synthesis is descriptive and does not pool effect sizes. The limited number of SDG 4 articles warrants caution when interpreting policy-level implications.

Publication year is reported next because it shows how recent the evidence base is. Recency matters for this study, since the research questions concern the period after remote learning during the pandemic. Table 2 shows the distribution of publication years from 2021 to 2025. The table is included to show whether the corpus reflects current research activity.

Table 2. Publication year of the included articles (N = 28)

Publication year	n	%
2021	1	3.6
2022	6	21.4
2023	1	3.6
2024	14	50.0
2025	6	21.4
Total	28	100.0

Half of the included articles were published in 2024, and 21.4% appeared in 2025. Together, these years accounted for 71.4% of the corpus. The remaining articles were published in 2021 (3.6%), 2022 (21.4%), and 2023 (3.6%). These figures describe the included corpus rather than publication trends across the wider field.

RQ 1: Main findings of Scopus-indexed studies**Table 3.** Summary of Scopus-indexed studies by theme

Theme	Study	Context and design	Main reported finding
Quantum learning	Khozaei et al. (2022)	Nursing students in Iran; quasi-experimental; 21 students per group analysed	Higher achievement and retention than lecture; motivation increased within the quantum group, with no significant between-group difference
Quantum learning	Nahar et al. (2022)	55 students in an Islamic elementary school; quasi-experimental	Significant difference in collaborative thinking skills ($p = .007$)
Quantum learning	Şahin & Kılıç (2024)	Solomon four-group design	Improved critical thinking and academic literacy; superior to project-based 6E learning for critical thinking, with no detectable difference for academic literacy
Ethnomathematics	Pratama & Yelken (2024)	Meta-analysis	Strong effect on mathematical literacy; effect sizes moderated by region, independent variable, and subject matter
Ethnomathematics	Näslund-Hadley et al. (2025)	Preschoolers in Panama; randomised evaluation	Positive effects on mathematical and ethnomathematical skills
Ethnomathematics	Supriyadi et al. (2024)	Needs analysis for a junior high school e-module; experts, one teacher, five students	Improved understanding and interest reported
Ethnomathematics	Astuti et al. (2024)	Junior high school teachers' beliefs	Most teachers believed numeracy could be fostered through ethnomathematics-based learning
Ethnomathematics	Payadnya et al. (2024)	Indonesian and Thai educators; questionnaire and interviews	Strong support among Indonesian educators (mean 4.77); need for practical classroom applications
Ethnomathematics	Nursyahidah et al. (2025)	Design research with prospective mathematics teachers	Learning trajectory integrating technology, Javanese ethnomathematics, and realistic mathematics education
Ethnomathematics	Aprinastuti & Amelia (2025)	31 pre-service primary school teachers; correlational	No significant relationship between mathematical thinking and resilience ($r = 0.116$)

Ethnomathematics	Meeran et al. (2024)	Intermediate Phase (Grades 4 to 6), South Africa; reflective study	Morabaraba game examined as indigenous mathematical knowledge
Ethnomathematics	Turmuzi et al. (2023)	Review of ethnomathematical research in Indonesian journals	Highlighted the application of ethnomathematics in elementary school mathematics
SDG 4	Rimba et al. (2025)	Provincial indicators in Indonesia; correlation and network analysis	SDG 4 held four of twelve priority indicators
SDG 4	Khan et al. (2024)	Malaysia, Indonesia, and Pakistan, 2000 to 2022	School enrolment positively associated with sustainable development

The three quantum learning studies reported outcomes involving achievement and retention (Khozaei et al., 2022), collaborative thinking (Nahar et al., 2022), and critical thinking (Şahin & Kılıç, 2024). Only Nahar et al. (2022) studied elementary students, focusing on Islamic religious education. Thus, the reviewed studies provide evidence across different outcomes and contexts, with limited direct evidence on elementary mathematics learning.

Most ethnomathematics studies reported positive or supportive findings, although Aprinastuti and Amelia (2025) found no significant relationship between mathematical thinking and resilience. The meta-analysis by Pratama and Yelken (2024) and the randomised evaluation by Näslund-Hadley et al. (2025) provide evidence from stronger research designs. Other studies examined teacher perspectives, instructional products, or smaller samples. Research at the elementary level remains limited among the reviewed sources, with relevant evidence from Meeran et al. (2024) and Turmuzi et al. (2023).

The SDG 4 studies addressed education at provincial and national levels. Rimba et al. (2025) identified quality education among Indonesia's provincial development priorities, while Khan et al. (2024) reported a positive association between school enrolment and sustainable development. Neither study examined classroom instructional approaches. These findings contextualise the relevance of education quality but do not establish the effects of a learning model.

RQ 2: A teacher's account of mathematics learning difficulties

Teacher 1 reported that sixth-grade students experienced difficulties with addition, subtraction, multiplication, and division. The teacher associated these difficulties with

students' limited familiarity with applying basic operations following online learning during the COVID-19 pandemic. Multiplication and division were described as common difficulties among upper-grade students. This account provides classroom context for the study.

The account is presented as a short qualitative description because it comes from a single interview. It has value as context, since it connects the wider evidence on learning loss with a concrete classroom situation. The account contains no measures of students' achievement and no information about learning before the pandemic. For these reasons, the account is used in the Discussion to interpret the relevance of the literature, and it is not used to evaluate any learning model.

RQ 3: Conceptual alignment of quantum learning and ethnomathematics

The conceptual alignment for RQ 3 was developed by comparing the phases of quantum learning described by Khozaei et al. (2022) with activities reported in ethnomathematics studies. Table 4 presents the proposed alignment for subsequent classroom testing.

Table 4. Proposed alignment of quantum learning phases with ethnomathematics-based activities (conceptual, not empirically tested)

TANDUR phase (international label)	Core activity in quantum learning	Illustrative ethnomathematics-based activity
<i>Tumbuhkan</i> (enroll)	Teacher connects the lesson to students' interests and learning purposes	Teacher elicits familiar cultural practices, such as traditional games or crafts, and relates them to the purpose of learning arithmetic operations
<i>Alami</i> (experience)	Students engage with concrete experiences	Students play or observe a locally familiar activity that involves counting, grouping, or arranging
<i>Namai</i> (label)	Concepts are named	Teacher and students name the mathematical structure observed, such as repeated equal groups as multiplication and equal sharing as division
<i>Demonstrasikan</i> (demonstrate)	Students show what they know	Students explain and present their strategies to peers
<i>Ulangi</i> (review)	Material is revisited	Students revisit the concept in different cultural contexts and short practice tasks
<i>Rayakan</i> (celebrate)	Effort and progress are acknowledged	Teacher acknowledges students' effort and progress

The proposed alignment draws on three sources. Khozaei et al. (2022) incorporated students' experiences into the experience phase, supporting the use of culturally familiar activities. Meeran et al. (2024) examined an indigenous game as a

source of mathematical knowledge, while Nursyahidah et al. (2025) demonstrated how ethnomathematics can be incorporated into a structured instructional design. The activities in Table 4 are author-proposed examples and remain untested in classrooms.

DISCUSSION

Quantum learning: positive and outcome-specific evidence (RQ 1)

The reviewed studies reported positive outcomes of quantum learning for achievement, retention, critical thinking, and collaboration. Khozaei et al. (2022) incorporated students' prior experiences before introducing new concepts, illustrating how the model structures learning around experience. However, the outcomes varied: motivation did not differ significantly between groups in Khozaei et al. (2022), and Şahin and Kılıç (2024) found no detectable difference in academic literacy between problem-based quantum learning and project-based 6E learning. These findings may reflect differences in participants, comparison models, and outcome measures. Nahar et al. (2022) provides evidence from elementary education, although the subject was religious education. Further research should examine specific outcomes, including retention of basic operations and motivation, in elementary mathematics classrooms.

Ethnomathematics: positive evidence with contextual variation (RQ 1)

The reviewed evidence supports the potential of ethnomathematics for mathematical learning, although outcomes vary by context and research design. Pratama and Yelken (2024) reported a strong effect on mathematical literacy, while Näslund-Hadley et al. (2025) found positive outcomes among preschool children. Supriyadi et al. (2024) reported improved understanding and interest in a small-scale needs analysis, which indicates potential rather than established effectiveness. Pratama and Yelken (2024) also found no significant difference in effect sizes by education level. Teacher perspectives remain relevant: Astuti et al. (2024) identified variation in teachers' beliefs, while Payadnya et al. (2024) highlighted the need for practical classroom applications. Professional development should therefore address both teachers' understanding of ethnomathematics and its classroom implementation.

Table 5. Variation in reported outcomes and possible explanations (interpretive)

Outcome	Pattern reported	Possible explanation
Achievement and retention	Higher in the quantum learning group than in the lecture group (Khozaei et al., 2022)	Skill-based content and an interactive environment; small sample and adult learners limit transfer to elementary mathematics
Motivation to learn	Increase within the quantum group, no significant between-group difference (Khozaei et al., 2022)	Differences in baseline levels and in the sensitivity of the measure
Critical thinking and academic literacy	Superior for critical thinking, no detectable difference for academic literacy (Şahin & Kılıç, 2024)	The comparison model (project-based 6E learning) may also support literacy
Mathematical literacy	Strong effect, moderated by region, variable, and subject matter (Pratama & Yelken, 2024)	Cultural and curricular context may shape how ethnomathematics is implemented
Mathematical thinking and resilience	No significant relationship (Aprinastuti & Amelia, 2025)	Correlational design within a single lesson context

The teacher's account in relation to pandemic learning loss (RQ 2)

Teacher 1 associated students' difficulties with basic arithmetic operations with remote learning. This account is consistent with broader evidence of learning deficits, which were larger in mathematics than in reading and in middle-income than in high-income countries (Betthäuser et al., 2023). Engzell et al. (2021) also reported little or no progress among primary students during home learning. These similarities provide context for the teacher's observations, although a single interview and the absence of pre-pandemic data do not establish causation. Reviews by Donnelly and Patrinos (2022) and Dela Cruz et al. (2025) further document research on learning loss and recovery. Diagnostic assessment of basic operations may help teachers identify students' needs before selecting instructional approaches.

Interpreting the proposed alignment (RQ 3)

The proposed alignment in Table 4 combines the instructional sequence of quantum learning with culturally familiar contexts from ethnomathematics. This interpretation is consistent with the use of students' experiences by Khozaei et al. (2022), the examination of indigenous mathematical knowledge by Meeran et al. (2024), and the structured integration of ethnomathematics, realistic mathematics education, and technology by Nursyahidah et al. (2025). The proposed framework uses quantum learning to organise instructional phases, and its outcomes cannot be inferred from these earlier studies. Future

quasi-experimental or mixed-method research could compare quantum learning, ethnomathematics, and their integration in elementary classrooms, measuring achievement, retention, and motivation separately.

Relationship to SDG 4

Education quality is relevant to Indonesia's sustainable development priorities. Rimba et al. (2025) identified SDG 4 among the priority indicators in provincial analysis, while Khan et al. (2024) reported a positive association between school enrolment and sustainable development. Because these studies address provincial and national patterns, their connection to the present classroom-focused study is conceptual. An instructional approach that improves mathematics learning could contribute to education quality, but this study contains no student outcome measures to establish such a contribution. Future evaluations should use classroom-level learning indicators when examining links with SDG 4.

Limitations and directions for future research

This study has several limitations. The interview involved one teacher at one school, and supporting documentation was not analysed separately. The reviewed studies varied in design, participants, and outcomes, and no formal quality appraisal was conducted. Future reviews could follow PRISMA guidance to improve reporting transparency (Page et al., 2021). The proposed alignment requires classroom testing with larger samples and quantitative or mixed-method designs, particularly for multiplication and division. Future studies could also examine digital technology as part of the instructional design, building on Nursyahidah et al. (2025).

CONCLUSION

This study reviewed literature on quantum learning, ethnomathematics, and SDG 4, examined a teacher's account of mathematics learning difficulties, and proposed a conceptual alignment between quantum learning phases and ethnomathematics-based activities. The reviewed studies reported positive outcomes of quantum learning for achievement, retention, critical thinking, and collaboration, alongside positive but variable outcomes of ethnomathematics for mathematical learning. The teacher's account of difficulties with basic operations provides contextual evidence consistent with broader findings on pandemic-related learning loss, although it cannot establish causation. The proposed alignment connects the two approaches to elementary mathematics education

in Indonesia and provides a basis for empirical investigation. Future studies should evaluate its effects on students' mathematics achievement and other specified learning outcomes.

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