

Decolonizing Health Data Literacy: A Systematic Review of Indigenous and Community-Based Mathematical Practices in Health Data Interpretation in Sub-Saharan Africa

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ABSTRACT

Background: Health data systems in Sub-Saharan Africa have been designed largely on Western biostatistical and epidemiological models, which devalue and disregard the Indigenous mathematical practices that communities in the region have used to interpret, communicate, and act on health-related information. This epistemological mismatch results in enduring knowledge gaps within communities, weak effectiveness of public health interventions, and the replication of a colonial knowledge hierarchy in the governance of global health.

Aims: This synthesis aims to synthesize the current state of knowledge on the nature and health outcomes of Indigenous and community-based mathematical practices in the interpretation of health data across Sub-Saharan Africa, and to inform decolonial mathematics education curricula and community health data literacy interventions.

Methods: This review is reported in accordance with the PRISMA 2020 statement and eMERGe reporting guidelines for meta-ethnography. Nine electronic databases were searched. A meta-ethnographic thematic analysis was used to synthesize findings from 52 studies distributed across West, East, and Southern Africa.

Results: The synthesis resulted in three broad clusters of Indigenous mathematical practices: quantifying relationships within the community and using ratios and proportions to describe; epidemiological infrastructure narrated through mnemonic structures that encode and transmit quantitative information about health in community places; and embodied spatial reasoning for the purposes of environmental health surveillance at the community level. In terms of health outcomes, these Indigenous surveillance and monitoring practices allow for an effective community-based approach, but the review shows that there are considerable risks associated with epistemological dissonance. This mismatch between Indigenous norms and Western biomedical norms typically involves not recognizing health issues, such as nutrient deficiencies, or not involving communities in formal health services.

Conclusion: The results show that Indigenous mathematical traditions are a complex and culturally relevant way of understanding, articulating, and acting on health-related information. Integrating community-based relational and spatial reasoning into decolonial mathematics curricula, these results offer crucial evidence base. Moreover, the results inform the design of community health data literacy interventions that are epistemically local and enhance the relevance of health communication and the promotion of epistemic justice in the African public health landscape.

Keywords: *Indigenous Knowledge Systems; Ethnomathematics; Health Data literacy; Mathematics education.*

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1. Introduction

Health data literacy, as used in this review, is conceptually narrower, and operationalized separately from, health literacy, which is defined as people's ability to obtain, understand and use health information in health-related decision making (Nutbeam & Lloyd, 2021; World Health Organization, 2023); whereas the former focuses on communication across multiple formats of information, the latter focuses on mathematical, statistical and quantitative-interpretive skills. Health data literacy at the population level is linked to lower rates of preventive health services, non-adherence to treatment, susceptibility to health misinformation, and reduced ability to engage meaningfully in health system governance (Berkman et al., 2011; Paakkari & Okan, 2020).

The question of health data literacy is specifically relevant in Sub-Saharan Africa, where the proportion of preventable diseases has remained disproportionately high compared to the rest of the world, and where community participation is now considered essential for the effective and sustainable performance of the health system. HIV/AIDS is responsible for around 57% of all HIV/AIDS deaths globally, while over 90% of all deaths from malaria globally are in this region, and maternal and child deaths that could be prevented by informed community action are the majority of deaths that could be averted globally (World Health Organization, 2023). In each of these, the mismatch between the health data available and communities' ability to use it to inform action is a serious barrier to translating biomedical knowledge into improved population health.

The principles of health data literacy, which are generally regarded as universal and objective, have been developed almost entirely within Western biostatistical and epidemiological frameworks (Woloshin & Schwartz, 2011). They are not neutral conventions, but a specific historical reaction to quantification, linked to social and institutional practices in the Global North. Their universalization, without critical consideration across Sub-Saharan Africa, constitutes an "epistemological imposition" that reflects a colonial knowledge hierarchy. The Global North's "centres of calculation", where the right to aggregate, interpret and validate health data has been monopolized, backs this hierarchy (Richardson, 2019).

The structural exclusion creates significant "epistemic wrongs," namely "credibility deficit" and "interpretive marginalization" (Bhakuni & Abimbola, 2021). The credibility deficit is what happens to Indigenous knowers in contexts where their culturally situated mathematical knowledge is regarded as 'unscientific'; the interpretive marginalization is what happens to the 'periphery's sensemaking of health and social reality, which ends up being excluded from the 'centre's collective knowledge making (Abimbola et al., 2024). Mainstream health frameworks value Western learning needs and scholarly standards, while marginalizing Indigenous intellectual traditions, rendering them as background events rather than legitimate spaces of scholarship (Abebe et al., 2021; Ramani et al., 2023).

The review focuses on Indigenous and community-based mathematical practices, defined here as culturally based systems of health data interpretation that involve: Relational quantification (Interpret numbers based on ratios, proportions and community resources instead of absolute, cardinal numbers), Narrative-based epidemiological infrastructure (Encoding, transmitting and retrieving quantitative trends and conditional probabilities via oral traditions, proverbs and storytelling), and Embodied spatial reasoning (Mapping health risks and environmental hazards with "emplaced" ecological knowledge and site-specific pattern recognition').

Engaging in public health decision-making and practice without accounting for these culturally based systems has serious implications for health outcomes and clinical practice in Sub-Saharan Africa. The use of standardized tools, including WHO growth charts, can cause "epistemological dissonance" due to the reliance on absolute cardinal numbers that may clash with local practices of relational quantification (Ahmad et al., 2011). In contexts such as Soweto, South Africa, caregivers use relational quantification to track children's development, relying on community-based reference trajectories rather than universalized biometric norms (Opesemowo, 2025). If not, these local observations that do not match formal charts can result in measurable health failures, including improper malnutrition diagnosis and premature discontinuation of exclusive breastfeeding (Ahmad et al., 2011). Moreover, the use of cultural markers rather than biometric measures directly affects health-seeking behaviour; parents in Southern Malawi may be less motivated to seek medical care for undernourished children because they tend to rely on physical indicators, such as adiposity, rather than biometric measures of stature (Flax et al., 2016). They are practices that rely on an oral tradition that conveys the message of risk (Agyepong et al., 2017) and on

embodied spatial knowledge that maps environmental risks (Takeuchi & Ishihara, 2020), showing that Indigenous mathematical systems are active cognitive frameworks that guide choices around health. Thus, the decolonization of health data literacy is a necessary precondition for health justice, as it helps overcome the "credibility deficit" created by colonial "centres of calculation" that have long excluded local epistemologies (Bhakuni & Abimbola, 2021; Richardson, 2019).

The systematic marginalization of these practices is not a mere slip-up, but a means of colonial governance and legitimation. The delegitimization of African ways of knowing was a political need to validate colonial authority over African social life, health and healing, as argued by Tobi (2020) and Quayson (2023). The underpinning of modern global health practices through this "coloniality of power" demonstrates a permanent separation of mathematical knowledge from a "colonial" past from a "colonial" present, whereby Indigenous mathematical thinking is considered inferior or obsolete (Ndlovu-Gatsheni, 2018).

This theoretical "interpretive marginalization" directly corresponds to the "epistemological dissonance" found in clinical and community practice. For example, local relational growth observations (Ahmad et al., 2011) often clash with the use of Western tools like WHO growth charts. Although these graphs are based on absolute cardinal values and standardized graphs, local care providers may also use relational quantification, which involves comparing a child's development to a community-based graph or marker of health such as adiposity (Flax et al., 2016). Not accounting for these relational frameworks leads to real health failures, such as parents' inability to recognize their baby's undernourishment when seeing a baby in the flesh rather than relying on the abstraction of the health care provider's biostatistics (Ahmad et al., 2011; Flax et al., 2016). Decolonizing health data literacy is therefore more than just a technical change; it is essential for "health data justice", which in turn requires an "epistemological delinking" from colonial hierarchies to secure community rights and representation in health governance (Rawson, 2026).

In recent years, ethnomathematics, the study of the mathematical practices of cultural groups, has accumulated various documents of Indigenous mathematical knowledge in Sub-Saharan African settings, including knowledge of geometry in craft-making, combinatorial knowledge in games and puzzles, quantitative knowledge in economic exchange, and spatial knowledge in architecture and navigation (Rosa & Orey, 2016). Studies on the use of this ethnomathematical scholarship in health data interpretation and health literacy are comparatively few, and there are limited systematic syntheses of the existing evidence.

While mathematics education was viewed as a space for developing skills and learning about mathematical topics of interest in the local context, it is now recognized as an emerging, yet under-theorized, interdisciplinary field with strong practical and policy relevance to global health. A mathematics education perspective embeds health contexts in mathematics curricula within the rich context of mathematics, and, with it, contextualized, culturally relevant, and socially meaningful mathematical learning, learning that ties formal mathematics to real-world problems meaningful to learners and their communities. Globally, efforts to build community health data literacy through mathematics-embedded educational practices provide a scalable, sustainable solution to enhance community health engagement and bridge the epistemological gap between health data producers and affected communities.

This intersection takes a decolonized form in Sub-Saharan Africa. Almost all students in the region are taught mathematics using curricula developed in the West, grounded in epistemological frameworks that lack a proper foundation in the mathematical knowledge students bring from their communities, as argued in the ethnomathematics literature (Battiste, 2014; D'Ambrosio, 2016). The result is a double epistemic deprivation; on the one hand, learners are not provided with tools and methods that have formal mathematical implications for the interpretation of health data, and on the other hand, they are not supported in articulating Indigenous mathematical practices into more instrumental tools that are more effective for the purpose of health data analysis. Mathematics education approaches that explicitly draw on Indigenous health data practices, guided by a thorough systematic review of what is known about them, have the potential to address both dimensions of the impoverishment.

The review finds no systematic synthesis of the specific, long-term health impacts of the continued use of these practices in Sub-Saharan Africa, especially clinical signs and symptoms of disease progression, morbidity and mortality. Secondly, there is an integrative or theoretical gap. No empirical study exists in the current literature that addresses the direct, joint relationships between relational quantification and narrative-based epidemiological infrastructure and embodied spatial reasoning together, and how they combine in their impact on health status and population-level trends in health changes over time; each is explored separately without an interrelationship that is theorised as a single mathematical intelligence used to address community health. Thirdly, there is a gap in methodology and authorship. The contributions of Indigenous Knowledge Systems to the development and production of clinical tools, health communication strategies and pre-service training for community health workers are still largely absent and the voices of indigenous authorship and framing of these are still underrepresented in scholarly production in Africa, the African voice in Indigenous-knowledge production is often heard from outside Africa. The three gaps are consequential when they are considered together; when the mathematical resources that are used to interpret illness, track child growth and coordinate environmental health-related practices in Sub-Saharan African communities remain invisible to the policy and curricular levers that shape health communication and mathematics education, they contribute to the credibility deficit and interpretive marginalisation that already characterises engagement with formal health institutions in the region (Bhakuni & Abimbola, 2021; Richardson, 2019).

This systematic review aims to fill these gaps by summarizing the evidence of Indigenous mathematical practices from across Sub-Saharan Africa. The review presents insight into the dual contribution to public health and mathematics education. In the field of public health, it creates an essential evidence base for epistemic justice, providing theoretical and empirical support for developing a more effective health communication strategy by adopting a local cognitive and mathematical approach rather than imposing an alien biostatistical approach. At the same time, in the field of mathematics education, the review presents fundamental community-based reasoning patterns, including proportional and spatial reasoning, as key components of the building blocks required to create decolonial, culturally relevant, and context-based mathematics curricula that value and build on mathematical practices that students bring from their communities (Bukari, 2026; Funez-Flores et al., 2024).

This systematic review will answer the following research questions in reference to the eMERGe guidance, and in light of the review's focus on Indigenous and community-based mathematical practices:

1. To map and collate qualitative and mixed-method evidence of Indigenous and community mathematical practices in the interpretation of health data in Sub-Saharan African contexts;
2. To transform these practices into lines-of-argument that account for how these practices influence health-data interpretation at the community, clinical and surveillance levels, through reciprocal and refutational meta-ethnographic synthesis;
3. To explore the tension between Indigenous quantitative epistemologies and the norm of biomedical/biostatistical epistemologies and its implications for understanding health data; and
4. To acknowledge limitations, gaps and implications of mathematics education, public-health training and decolonial health-data policy in Sub-Saharan Africa.

This review provides the first meta-ethnographic synthesis that makes explicit the connection between ethnomathematics, epistemic justice and health data literacy in the sub-Saharan context, which has not been covered by previous single-discipline reviews.

2. Methods

Research Design

This study used a qualitative meta-ethnographic design comprising seven phases, as suggested by Noblit and Hare (1988) and detailed in the context of health and education research by Flemming et al. (2019). Meta-ethnography is a systematic, interpretive qualitative synthesis methodology that does more than simply summarize the findings of multiple studies; it also creates new, higher-order conceptual interpretations, translations, and syntheses, delivering theoretical insights not found in the individual studies included in the analysis (France et al., 2019). This synthesis follows the PRISMA 2020 statement and the eMERGe reporting guidelines, which explicitly follow the

seven phases of the meta-ethnography framework to ensure rigorous reporting and transparency across the synthesis. For three reasons, this design is considered the most epistemologically suitable methodology for the research's purposes. The reason to consider this design as the most epistemologically suitable methodology in relation to the purposes of the research is as follows:

First, the phenomenon studied (Indigenous and community-based mathematical practices in Sub-Saharan Africa) is interpretive in nature. It's about sense-making, culture, and epistemological stance and not about measurable outcomes that can be aggregated quantitatively. A qualitative synthesis methodology is thus more suitable than a statistical meta-analysis (Toye et al., 2014) or than a descriptive narrative review alone. Second, meta-ethnography emphasizes the development of new theoretical understanding, which resonates with the theoretical commitments of the study to decolonize the relationship between Indigenous mathematical knowledge and health data literacy, a relationship that is not simply evident in the literature but that produces a reconceptualization of this relationship. Third, the explicit focus of the methodology on the theoretical frameworks and epistemological assumptions discernible in the included studies makes it especially suitable for a review that itself asks epistemological questions about the nature and representation of Indigenous mathematical knowledge and the epistemological assumptions that have guided these representations.

Search Strategy

The databases searched for articles were 9: MEDLINE via PubMed, EMBASE, Global Health (CAB International), CINAHL, ERIC, PsycINFO, African Journals Online (AJOL), Scopus, and Web of Science Core Collection. The search strategy included the following concepts grouped in clusters: (1) Indigenous knowledge, decolonial, ethnomathematics, traditional mathematical practices, (2) health data, health literacy, health numeracy, epidemiological interpretation, (3) community health, community-based health, (4) Sub-Saharan Africa, with individual country names as search terms. In order to enable the replication, field tags, MeSH/ free-text combinations and date filters were added to the search in MEDLINE; the same search string was used but with adaptations to the other databases as specified in Supplementary Appendix A2, namely Scopus, Web of Science, CINAHL, Embase, African Journals Online, EBSCOhost, Google Scholar, the Directory of Open Access Journals and the South African ETD Portal. The search was re-run within 30 days of submission to capture late-indexed records.

Inclusion criteria

The following criteria were considered for inclusion of sources, the sources were set in Sub-Saharan African contexts; the sources included at least one of three key elements in Indigenous or community-based mathematical practices: Relational Quantification (Understanding the health data in terms of ratios, proportions, and community resources available, instead of in terms of absolute cardinal), Narrative Based Epidemiological Infrastructure: (The encoding and transmission of quantitative health trends and conditional probabilities through oral traditions, proverbs and storytelling), Embodied Spatial Reasoning (Mapping health risks and environmental hazards through site-specific pattern recognition and ecological knowledge); sources were published in English between 2010 and 2025; and sources were of methodological and/or theoretical substance and contributed meaningfully to the interpretive synthesis. Unlike the grounded-theory sampling, in which the three analytical categories emerged as themes in the process of data analysis, this design is a priori concept-driven, and therefore not a product of the synthesis. Hence, a methodological note on design is warranted here and it is important to distinguish this design from the grounded-theory sampling.

Exclusion criteria

Excluded sources were those that mentioned only Western frameworks (e.g., biostatistics or epidemiology) and did not mention Indigenous or community-based mathematical knowledge systems, or that were so poorly developed that they were not clearly presented for quality assessment.

Selection Process

The title and abstract were independently screened by the researcher and a research assistant for the pre-specified criteria. The process of full-text review of potentially eligible sources followed the same process. Issues were addressed both times through discussion and consensus. The selection process is illustrated in the PRISMA 2020 flow diagram in Figure 1.

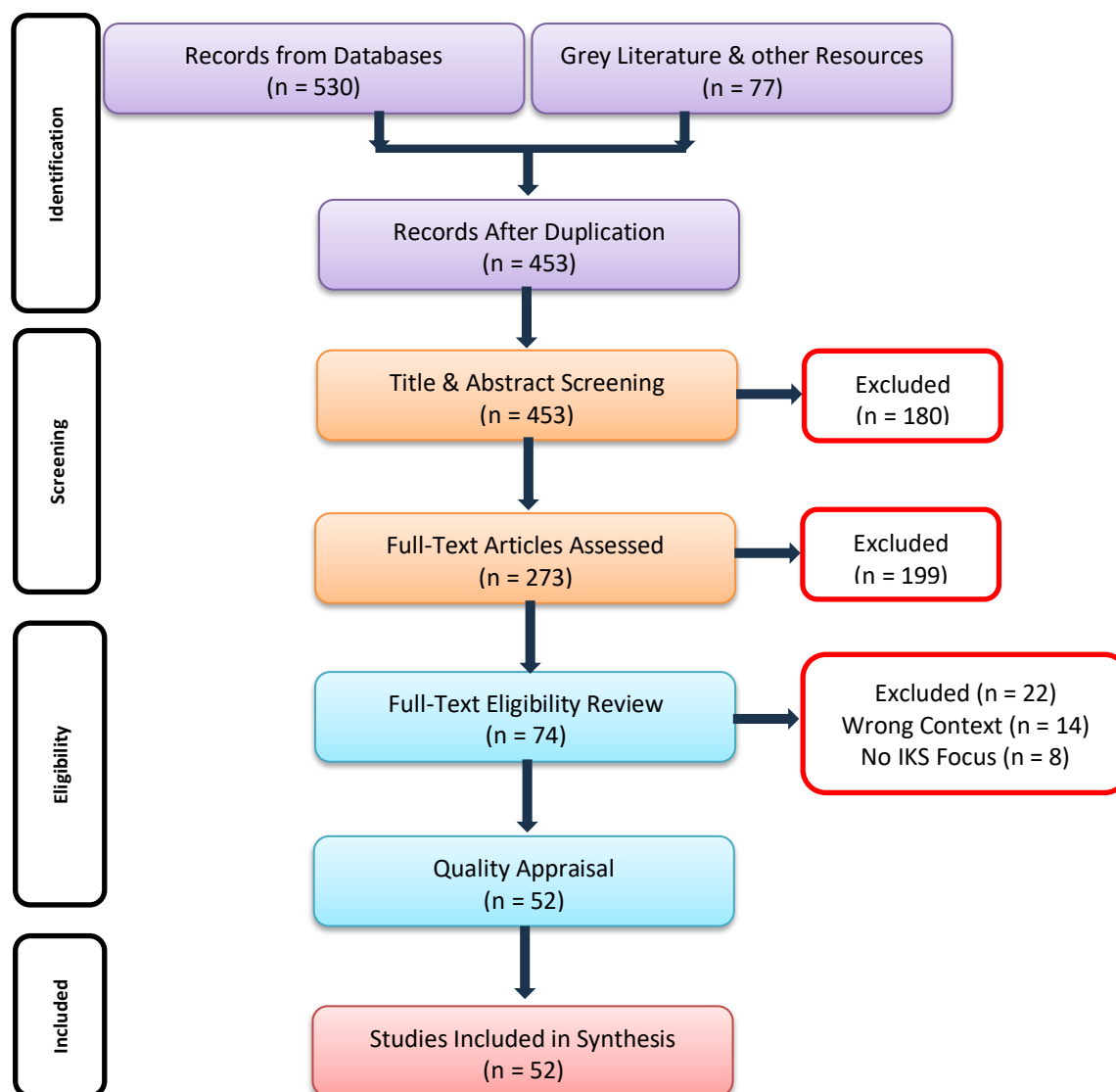


Figure 1. PRISMA Flow Diagram

Quality Appraisal

The Critical Appraisal Skills Programme checklist for qualitative research and the Joanna Briggs Institute Qualitative Assessment and Review Instrument to assess methodological rigour and potential for bias were adapted for quality appraisal (Sattar et al., 2021; Toye et al., 2014). Appraisal was operationalized using a 'conceptual richness' lens as a response to epistemological concerns of the potential undervaluation of Indigenous research methods by Western traditions. Studies were assessed using a 'face validity' approach and adequate conceptualization to translate the study, rather than excluding studies on the basis of a rigid procedural checklist, which is more likely to favour medical journal articles and detail ethnographic reports. A study was judged to be high quality if it provided 'key' conceptual contributions in the three pillars of mathematical practice, irrespective of whether it followed the standard reporting style found in most Western biostatistical research papers.

Inter-rater reliability for quality appraisal was calculated on 25% ($n = 13$) of the included full-text studies, which were selected randomly. The conceptual-richness lens (criteria: (i) depth of ethnographic engagement with Indigenous mathematical practice; (ii) contextualisation of mathematical practice in health-data interpretation; (iii) reflexivity regarding knowledge-system asymmetries; (iv) evidentiary specificity regarding community-level practice) was applied independently by the lead researcher and research assistant.

Data Extraction and Synthesis

The following sources were considered for the data extraction. Bibliographic and contextual information, study design and methodology, country and community context, specific health outcomes (clinical indicators such as growth markers and infections, morbidity, and mortality related to the use of these practices), population characteristics, theoretical and epistemological framework used, description and characterization of Indigenous mathematical practices (relational, narrative, or spatial), key findings relevant to each research question, and author interpretations and conclusions. The lead researcher extracted the data, and the research assistant verified its extraction from the included sources.

The meta-ethnographic approach, with seven phases, was used to synthesize the data. This involved a reciprocal translation of findings across the 52 included studies to examine the relationship between Indigenous mathematical thinking patterns and health status. Synthesis of health outcomes was carried out by mapping the 'epistemological dissonance' between local relational observations and formal clinical indicators (WHO growth charts), and how this influences clinical decision-making and care-seeking behaviours.

Curriculum and Intervention Identification

It employed a second analysis of the abstracted mathematical reasoning patterns and utilized the techniques of the 'dual contribution' of this review. Evidence was systematically organized to reveal relationships between local relational and spatial logic and the mathematical foundations that serve as building blocks for mathematics education. At the same time, it found data that demonstrated the effect of these mathematical approaches on the effectiveness of health intervention design. This enabled the synthesis to identify ways to integrate Indigenous mathematical resources into formal health systems, thereby developing culturally responsive curricula and more effective public health communication strategies.

Ethical Considerations

This study was derived from what has been published and distributed in the public arena and in the grey literature and therefore did not require Institutional Review Board approval to collect primary data. The study, however, was carried out with an ethic of epistemic respect towards the communities whose knowledge practices are represented in the included literature. All sources were examined critically to determine whether they were conducted in partnership with the communities they represent, and the representation of knowledge in the included literature is explicitly discussed with respect to its ethical aspects.

3. Results

Study Selection and Characteristics

The database search identified 530 publications from the systematic search process across nine electronic databases and supplementary grey literature sources. After 77 duplicate records have been removed, 453 unique records have advanced to the title/abstract screening process. Of these, 180 were discarded from the title and abstract because they were not geographically relevant, lacked mathematical or quantitative content, or were obviously unrelated to the phenomenon under study. The other 273 records were obtained for full-text analysis, and 199 were rejected for the reasons outlined in Figure 1. After the full-text eligibility review and quality appraisal, only 52 sources were included in the final synthesis. As specified in the Methods, where third order interpretations (novel constructions that go beyond what any single included study claims (Noblit & Hare, 1988) are offered, this is indicated with the phrase 'Third-order interpretation:' preceding the construct; likewise, 'Synthesis of included studies:' precedes direct synthesis of the included studies.

Mathematical Practices and Health Outcomes

Four main types of mathematical practices emerged from the synthesis, representing a unified "mathematical intelligence" applied to health:

Counting Systems and Numerical Foundations

Indigenous counting systems are used to reinforce the identification of numerals and build functional numeracy (Eze & Yenogha, 2024). These systems focus on relational quantification of the health data, which is the health data interpreted as ratios, and community resources rather than absolute cardinal value (Opesemowo, 2025).

Risk Estimation Approaches

Risk estimation is based on the comparison of the health phenomena of the present with the resources of the households or the labour capacity. Cultural signals, such as adiposity, are embodied signals that are more important to caregivers than stature measurements in Southern Malawi (Flax et al., 2016). Seeking medical intervention for undernutrition in children is delayed when there is a disconnect between the perceived 'plumpness' (relational markers) and clinical standards (Flax et al., 2016).

Visual Interpretation Methods

Communities use embodied spatial reasoning and geometric pattern recognition to map environmental health hazards (Takeuchi & Ishihara, 2020). The "distributed epidemiological intelligence" is generated by analyzing the geometric distributions of water bodies and settlement layouts, enabling community members to identify vector breeding sites (Takeuchi & Ishihara, 2020).

Communal Decision-Making Practices

There is a narrative-based epidemiological infrastructure in place in which elders are 'epidemiological archivists' (Agyepong et al., 2017), sustaining communal decision-making. But this epistemological mismatch has been documented in clinical consequences between these narrative frameworks and Western biostatistical tools. For example, using standardized numerical growth charts (which are in conflict with relational observations) has been empirically shown to be associated with delayed detection of infant malnutrition and early cessation of exclusive breastfeeding (Ahmad et al., 2011).

Research Gaps and Underrepresented Domains

Many of the studies (52) are useful, but significant gaps remain. The health domains studied are well represented by infectious diseases (malaria, HIV/AIDS), but non-communicable diseases (diabetes, hypertension) are critically underrepresented. Very little research exists on the Indigenous approach to health monitoring for chronic, long-term conditions. Youth populations and traditional Indigenous practices are not considered, and there is an apparent "urban bias" that traditional knowledge is a rural phenomenon. As a result, there is a lack of cross-cultural comparative studies across national borders that will enable the development of a unified model of African Indigenous mathematical literacy (Xu & Ball, 2024).

Pedagogical and Intervention Implications

The synthesis makes it clear that decolonizing health literacy cannot occur without a change in the practice of education and public health. Conceptual Participation: Mathematics Education Curricula: Integration of traditional counting and spatial patterns into instruction improves conceptual participation (Bukari, 2026). Mathematics education should move towards "design space" pedagogical models that reimagine mathematics education as a 'space' inclusive of local cultural logic. Health Literacy Interventions: Effective interventions must not only "translate" Western biostatistics but also embrace communities' narrative-based infrastructure. To prevent "credibility deficits" and "interpretive marginalization" (Bhakuni & Abimbola, 2021; Rawson, 2026; Richardson, 2019), health institutions need to ensure that their formal communication process resonates with the relational and spatial frameworks identified in this synthesis.

4. Discussion

Indigenous Quantification as Relational Epistemology

Traditional mathematics is not just a cultural artifact, but a cognitive practice that has an impact on clinical outcomes. The influence is mainly manifested in a relational quantification of health data, which is the process of interpreting health data with respect to community resources that are available and ratios (Opesemowo, 2025). There is evidence that, if these practices are neglected, it causes real health failures. For example, in Southern Malawi the focus on embodied cultural indicators, such as adiposity, over biostatistical indicators, such as body measurements or growth charts, means that infant malnutrition is not diagnosed as quickly as it should be when cultural indicators fail to match biostatistical ones (Ahmad et al., 2011; Flax et al., 2016). In addition, communities can be viewed as a "distributed epidemiological intelligence", assisting in the identification of breeding areas of the vectors, and the understanding of the speed at which the community level interprets the risk and seeks care (Opesemowo, 2025; Takeuchi & Ishihara, 2020).

The most theoretically generative finding of the synthesis is the basic logical framework of the Indigenous mathematical health practices in Sub-Saharan African contexts. The majority of the sources included ($n = 38$) provided evidence supporting the claim that Indigenous quantification is not an approximation of Western cardinal number systems but rather a type of mathematical thinking qualitatively unique and based on relational number quantities. The result is a finding that emerged from the translation of concepts across studies from widely divergent disciplinary backgrounds, such as medical anthropology, ethnomathematics, community health, and linguistic anthropology, which used different terminological schemes to describe structurally cognate phenomena as they appeared in the synthesis.

In the field of communicable diseases, a few empirical studies showed that community members in rural Kenya, Tanzania, and Uganda measured and communicated the burden of disease through relational proportions rather than absolute numbers. The severity of a malaria season was not expressed as a number of people sick, but as a ratio to available caregivers, agricultural labour or household resources (Parker et al., 2009; Were et al., 2018). Such a relational quantification is not imprecision; it is a mathematically sophisticated quantification of risk that is contextualized in relation to community vulnerability that cannot be conveyed by pure numbers. This synthesis identified this practice across 12 geographically distinct studies, indicating that relational quantification is a widespread aspect of Indigenous mathematical health reasoning practice in the region, rather than a culturally specific local practice.

In maternal and child health, included studies in Ghana, Nigeria, and South Africa described the mathematics used by community members to evaluate children's nutritional status, growth curves, and feeding intake. In both settings, the most common approach to quantitative assessment was relational (that is, comparing the child's development with a community-based reference trajectory), as well as pattern recognition within temporal sequences, and estimation of conditional probability in culturally familiar narrative forms (Madhavan et al., 2017; Modjadji, 2021). These practices were described by several authors as community-based developmental surveillance systems that were quite effective without the use of formal measurement instruments. The results of this meta-ethnographic translation across health areas and geographical settings yielded the higher-order concept of relational epistemology as the organizing principle of Indigenous mathematical health reasoning. The idea that made itself apparent in their reflections, not used in any one of the studies included, is that Indigenous quantification in Sub-Saharan African health situations is built on the mathematical relationship between phenomena (ratios, proportions, trends, and conditional relationships) and not on the assignment of absolute numerical values to isolated phenomena. This relationality is not a constraint on Indigenous mathematical ways of thinking but rather a complex epistemological perspective, and, in many ways, more appropriate for understanding community health dynamics than the Western focus on standardized individual measures from a biostatistical perspective.

Theoretically, this finding matters to mathematics education. If the mathematical structure of Indigenous health reasoning is relational, rather than absolute numerical, then mathematics curricula that emphasize proportional reasoning, ratio, pattern recognition, and conditional thinking are not moving away from mathematical rigour in schools, but furthering it, and adapting to the mathematical epistemology that is already

present in learners' communities. This implication for the curriculum is that relational thinking is not a lower-order skill that comes before formal mathematical abstraction; it is a sophisticated mathematical skill that formal learning ought not to replace.

Narrative as Epidemiological Infrastructure

The second great theme to emerge from the synthesis relates to how oral and narrative traditions are used as tools for mathematical infrastructure to support community-level health data management in Sub-Saharan Africa. In 29 included sources across the communicable disease, maternal health, and nutritional domains, evidence suggests that storytelling, proverbs, riddles, and oral historical narratives do not only convey health information in a general sense, but that they are structured systems that encode, transmit, and retrieve quantitative health information with systematic underestimation of the degree of precision and reliability. Western health communication scholarship has assigned to the medium.

In West Africa, particularly Ghana, Nigeria, and Senegal, studies have shown that mathematical structures can be found in traditional narratives of disease, that these narratives are culturally accessible, and that the mathematical information in these narratives is specific (Lamanna, 2018; Kamalu, 2020). These mathematical elements are not just incidental to these stories but are structurally embedded in the very narrative form itself, through the use of proportional language, temporal sequencing, comparative reference, and conditional constructions, which serve the same epidemiological functions as formal mathematical summaries but are accessible to community members who may lack formal mathematical training.

One of the most striking findings was from three of the studies included, which detailed the role of community elder knowledge-holders as what the synthesis describes as epidemiological archivists who maintained detailed oral records of disease patterns across multiple decades with mnemonic mathematical structures that preserved information about relative disease burden, seasonal variation, and intergenerational health trends that were not captured by formal health information systems (Agyepong et al., 2017; Makhubele, & Nyahunda, 2018).

The concept of narrative as epidemiological infrastructure was further supported by findings from maternal and child health contexts across southern and eastern Africa. In these situations, oral traditions served as systems of community-level growth monitoring that captured normative patterns of growth and quantitative thresholds indicating concern for health, expressed in proverbs, songs, and structured narrative transmission by women (Mchome et al., 2019; Modjadji, 2021). Such practices were essentially a distributed health-monitoring system that ran continuously and without external support.

The synthesis of these findings resulted in a higher-order interpretation with clear implications for health communication and mathematics education. Structural misalignment between formats and community members' consistent ways of reasoning about health is not a problem for mathematically unsophisticated community members; rather, the formats used to communicate formal health data do not align with the relational, narrative forms of mathematical argumentation that community members have at their disposal. Mathematics that fosters the ability to encode phenomena in health care in either a narrative-mathematical or a formal-statistical representation, without replacing one with the other, would tackle this misalignment at its epistemological level.

The systematic push out of these mathematical frameworks is a clear reflection of the "colonial matrix of power" (Mothoagae, 2022). In the past, colonial governments have attacked local medical and mathematical learning, demanding that they conform to the "medical orthodoxy" of Western medicine (Ude, 2022). This phenomenon is known as "medico-neocolonialism," and it remains to impose the "centres of calculation" of the Global North on Indigenous practices (Richardson, 2019; Ude, 2022). The neglect of African epistemologies stems from a form of "epistemic violence" that undermines the value of non-Western epistemologies (Chance et al., 2025; Tosam, 2024). Formal systems both define Indigenous reasoning as "anachronistic" or "pseudoscience" and privilege Western biostatistical rationality as the only source of truth (Tosam, 2024; Wuta, 2025).

Embodied Spatial Reasoning and Environmental Health Surveillance

Spatially embedded mathematical health reasoning was found to be particularly rich in the agricultural and nutritional domain (Filho et al., 2022). From Kenya, Uganda and Tanzania, there is documentation of community-based systems of assessing food security risk using sophisticated analysis of spatial variation in land productivity, rainfall distribution and crop yield across micro-ecological zones, an agricultural and epidemiological reasoning, applied to the assessment of nutritional health risk through the mathematical analysis of spatial and temporal variation in food production (Kangalawe, 2012; Rufino et al., 2013). These systems were seen as distributed spatial epidemiology, a type of surveillance system within communities, mathematically organized to monitor nutritional health risks by analyzing environmental indicators in space.

The synthesis also included information on spatial mathematical practices for managing disease vectors reported in several of the studies included. In malaria-prone areas in West and East Africa, communities used spatial reasoning skills in distributing water bodies, estimating proportional area, and geometrically modeling the distribution of vegetation, as well as the distribution of settlements, to locate vector breeding sites and to coordinate collective mosquito control activities, which involved spatial reasoning skills (Dongus et al., 2007; Mwangungulu et al., 2016). The studies included in this document have documented these practices as effective in providing epidemiologically significant outcomes in the absence of formal spatial analysis tools, particularly community-based spatial mathematical reasoning.

The other dimension was the contribution of the knowledge of the traditional healing landscape to spatial reasoning in the community. In South Africa, Zimbabwe and Mozambique detailed community knowledge of the spatial distribution of medicinal plants, the geometric organization of the healing space, and the relationship between environmental features and health phenomena were documented, including sophisticated mathematical understanding of ecological spatial relationships, which is not captured in Western biomedical geography, but is embedded in cosmological and relational ontological frameworks (Kamsu-Foguem, Diallo, & Foguem, 2013; Carstens & Preiser, 2024).

The higher-order interpretation that emerges from the lines of argument synthesis across this work is that community spatial mathematical health practices are an example of distributed epidemiological intelligence, continually maintained, locally calibrated, and grounded in the community's ecological and social geography. This intelligence is not a rudimentary precursor of epidemiological surveillance, but a complementary tool that can never be replaced, and its systematic elimination from health information systems constitutes an epistemological loss with direct impacts on public health responses in the region. This theme suggests that spatial reasoning in health contexts is epistemologically important for building the more formal spatial reasoning skills needed in the academic curriculum, in which the spatial-mathematical skills students bring from their communities are not only motivating but also epistemologically essential.

Epistemological Dissonance and the associated Health Consequences

There is significant epistemological conflict and institutional resistance in the process of incorporating Indigenous practices into formal health systems. Educational institutions with fixed curricula and insufficient teacher training are often inadequate for integrating Indigenous Knowledge Systems (IKS) (Kaziya, 2025). The question of a pluriversal approach, a system of medical and mathematical coexistence without hierarchy, is still under discussion (Chance et al., 2025; Mothoagae, 2022). The effectiveness of IKS, however, was proven during the COVID-19 crisis, when local groups mobilized local knowledge to address the crisis despite their marginalization in formal policies (Mzimela & Moyo, 2024). This implies that the most practical way forward to achieve sustainable socio-economic development is through the "hybridization" of Western and indigenous systems (Wuta, 2025).

However, evidence from 24 of the included sources consistently shows that Sub-Saharan African communities were using sophisticated spatial reasoning practices in which they identify, map, and communicate the challenges of environmental health using mathematical knowledge in embodied, place-based, and ecological ways that were not in the coordinate geometry and spatial statistics of formal environmental health science. In the field of environmental health, included studies from rural communities in Mozambique, Zimbabwe and South Africa explored how community members utilized spatial pattern recognition, namely, recognizing the geometric

arrangement of disease incidence over landscape features; comparing the geometric arrangement of water sources, vegetation patterns, and settlement layouts and recognizing their association with disease patterns; using the geometric reasoning to identify environmental risk factors and guide collective health protective action (Ezeanya-Esiobu, 2019; Chahine, 2020). These practices involve mathematical competences that are directly cognate to spatial statistical methods in formal environmental epidemiology: spatial pattern recognition, geometric reasoning about distributions, and proportional spatial estimation, and are not produced through formal statistical analysis but rather through embodied, community-based reasoning.

The fourth and most important theme that has emerged from the synthesis concerns systematic differences between practices of Indigenous mathematical health data collection and those of formal health data collection in Sub-Saharan Africa using biostatistical methods, and the impact of these differences on health outcomes. The theme was mainly generated by cross-reading results from studies that found health communication and community health engagement were lacking, alongside those that documented that Indigenous mathematical health practices were rich and sophisticated. The synthesis of these streams of evidence yielded a coherent and troubling picture of the structural misalignment, or epistemological dissonance, of the mathematical tools with which communities think about health, and the tools through which health institutions communicate health information.

In 22 of the included sources, spanning communicable disease to maternal health and nutrition, evidence of systematic failures in community understanding of formally communicated health information was documented, and this was found not to be a consequence of inability to do mathematics, but rather of epistemological misalignment. Opesemowo (2025) documented that these community members could not interpret standardized growth charts, percentage-based risk statistics, epidemiological curve diagrams, and probability-framed treatment benefit information, not because these community members lacked the mathematical capacity for proportional and probabilistic reasoning, but rather because these formal representational formats were structurally misaligned with the relational, narrative, and spatially embedded mathematical forms through which those community members would habitually reason about the same phenomena.

There are several studies in the bundle that recorded in great detail the health consequences of this epistemological dissonance. In the maternal health context, the use of the numerical-absolute approach of monitoring growth on the antenatal card was correlated with delayed recognition of infant malnutrition among caregivers, who had an understanding of their child's situation based on relational comparative language but were not able to interpret the standardized numerical indicators used in formal health communications (Mishra, M., & Banerjee, 2017; Opesemowo, 2025). Community members' lack of understanding of formally presented epidemic curve data was not linked to community disengagement with health information, but rather to the epistemological inaccessibility of the data (due to the inability to connect with the community members' relational mathematical frameworks through which they interpreted and communicated health risk during the epidemics) (Rubinelli et al., 2022; Smith et al., 2025).

The synthesis also revealed a trend of what several of the included authors described as epistemological humiliation, where community members experienced community members' Indigenous knowledge of mathematical health being dismissed, pathologized, or ignored by formal institutions, resulting in alienation from formal health services and having implications for health, seeking beyond the interactions in which the dismissal occurred (Nemutandani, Hendrick & Mulaudzi, 2020; Chance, Theophile & Loe, 2025). This discovery has implications for trust and community health engagement within health systems, which are well-documented areas of the health literature in sub-Saharan Africa but have not often been associated with the epistemological aspects of mathematical communication.

In the lines-of-argument reputational synthesis of the evidence at the earliest sections, the health impacts of epistemological dissonance were understood not to be due to mathematical disaffirmation by communities, but to epistemological disaffirmation within health systems, health systems that are rich in the development of sophisticated biostatistical communication tools and almost devoid of understanding and engagement with the mathematical frameworks that communities actually use to make sense of health. This isn't just an academic fact; it's a public health fact with implications for the design of health communication interventions, the training of community health workers, and the mathematics education of future health professionals.

Table 1. Summary of Synthesized Themes and their Implications

Theme	Studies (n)	Core Construct	EHLM dimension	Curriculum Implications
Indigenous quantification as relational epistemology	38	Relational quantification, rather than absolute-numerical, is the primary mathematical structure of Indigenous health reasoning	Epistemological	Foreground proportional, relational reasoning, and contextualize this in health phenomena
Develop communicative competence between narrative-mathematical and formal-statistical representations	29	Narrative as epidemiological infrastructure: Oral and narrative traditions as community-level quantitative health data management systems	Communicative	Develop translational competence between narrative-mathematical and formal-statistical representation
Embodied spatial reasoning and environmental health surveillance	24	Spatially embedded mathematical practices as distributed epidemiological intelligence	Relational	Integrate spatial reasoning in health contexts as a primary site of ethnomathematical curriculum development
Epistemological dissonance and its health consequences	23	Structural mismatch between Indigenous mathematical health frameworks and Western biostatistical communication, with documented health consequences	All three dimensions	Design assessment and communication tools that engage relational, narrative, and spatial mathematical competences alongside formal statistical literacy

EHLM = Ethnomathematics-in-Health-Learning Matrix, a four-dimension coding frame used in data extraction to capture the educational modality by which a mathematical practice is transmitted.

The results of this study are consistent with the “sociopolitical turn” in mathematics education (Fúnez-Flores et al., 2024). There are dualisms that divide the mind from the body and the natural from the non-natural in the world. Decoloniality theory deconstructs such dualities that separate the mind from the body and the nature from the non-natural in the world. What is asked of them is “productive struggles” that align with the Global South scholarship that wants to recover “vernacularized” knowledge (Muller, 2025; Rawson, 2026). Indigenous health data literacy is not abstract and universal, like the models used in the West to guide the interpretation of biostatistical data, but, rather, “emplaced” and “embodied” as methodologies that focus on relationships and storytelling (Opesemowo, 2025; Takeuchi & Ishihara, 2020).

To take the learning out of the classroom and into real practice, the evidence relates to two specific areas:

Curriculum Transformation

Teachers should embrace the Curriculum Adaptation Model for Culturally Responsive Mathematics Instruction (Kaziya, 2025). This includes utilizing sociocultural formats of caring (in rural areas, the “Herbalist Masters”) as tools to teach spatial patterns, volumes, and ratios. The incorporation of the moon cycle and mental computation of market transactions enables pupils to observe the logic in their community mathematically (Kaziya, 2025; Opesemowo, 2025).

Community-Based Health Interventions

Public health agencies need to move away from the “top-down” approach to “epidemiological infrastructure” by using narrative communication. This demands training community health workers with relational markers alongside formal data to minimize “credibility deficits” (Bhakuni & Abimbola, 2021; Flax et al., 2016). The use of IKS as a “sine qua non” for sustainable development contributes to more equitable, contextually relevant interventions (Wuta, 2025).

5. Conclusion

This systematic review merged research findings from 52 studies from Sub-Saharan Africa, Ghana, South Africa, Nigeria, Kenya, Uganda, Senegal, Zimbabwe, Mozambique, and Tanzania to show that Indigenous and Community-Based Mathematical Practice is a complex and culturally relevant way of understanding, articulating, and acting on health-related information. Four overlapping themes emerged from the meta-ethnographic synthesis: Indigenous quantification as an epistemology of relations, narrative as epidemiology infrastructure, embodied spatial reasoning as an environmental health surveillance system, and epistemological dissonance between Indigenous mathematical epistemologies and formal biostatistical communication systems. These studies, in combination, reject deficit assumptions that Indigenous peoples lack mathematical capabilities and demonstrate that Indigenous peoples have mathematical traditions that support health decision-making, disease surveillance, risk communication, and community health governance.

Mathematical practices that are most relevant to health data interpretation were identified: relational quantification (in which ratios and availability of community resources, rather than absolute values, are emphasized); narrative-based epidemiological infrastructure (health patterns are archived through intergenerational story-telling and proverbs); embodied spatial reasoning (intentional geometric mapping of environmental health hazards); and risk estimation (which involves comparing current health phenomenon with the availability of labour or embodied markers in the household).

This review finds that such use of Indigenous mathematical practices is directly and meaningfully linked to health outcomes, specifically health-seeking behaviour and risk identification. When formal biostatistical communication does not align with local reasoning, this has real clinical consequences, such as failing to recognize infant malnutrition or prematurely stopping exclusive breastfeeding because of the use of relational markers (adiposity) rather than clinical growth charts. Embodied spatial reasoning, on the other hand, is an important environmental surveillance tool, as communities can determine their own vector breeding sites and collectively protect themselves.

Finally, increasing health data literacy and mathematics education in the region calls for a decolonial transformation. African epistemologies can be marginalized by the "deficit models" of health systems, which are necessary to attain epistemic justice (Rawson, 2026). In the context of mathematics education, this means implementing the Curriculum Adaptation Model for Culturally Responsive Mathematics Instruction, which involves aligning the mathematics formal syllabus with Indigenous cultural understandings, such as the mental arithmetic of market transactions and the ratio logic of "Herbalist Masters" (Kaziya, 2025). These narrative and relational infrastructures are a precondition for public health communication to shift and reduce clinical delays, while cultivating resilient, contextually relevant health governance (Wuta, 2025).

6. Recommendations

To promote cultural responsiveness and epistemic justice, mathematics curricula and pedagogies in Sub-Saharan Africa should go beyond Western mathematics models and involve Indigenous knowledge holders and communities in co-developing instruction. This collaborative approach, in particular the use of the Curriculum Adaptation Model, will help to reconcile the formal syllabus with the relational logic and mental arithmetic already used in these communities. In addition to the classroom, public health agencies need to intentionally create community health data literacy initiatives that are not deficit-based and grounded in mathematical practices rather than biostatistical models. This must involve transitioning from "top-down" communication to narrative and spatial representations of risk, as this would help address the interpretive marginalization and credibility gap that Indigenous people encounter. These transformative efforts rely on ongoing collaboration among educators, public health workers, mathematicians, and community members to develop a cohesive proposal for culturally competent health governance.

Additionally, there is a pressing need for rigorous primary studies to assess the immediate health impacts of incorporating Indigenous mathematics practices into the curriculum. To address the current “rural bias”, further research and interventions are needed in under-researched areas, as well as in urban Indigenous practices and in chronic health conditions. Lastly, stakeholders need to promote the inclusion of IKS in a strong policy agenda, viewing it as a valid and relevant source of health communication and decision-making. This means that IKS is not optional but a prerequisite for sustainable socio-economic development, and that health systems must be contextually appropriate and equitable to achieve both epistemological delinking and equitable health systems.

Conflict of Interest

There is no conflict of interest. Nothing to disclose.

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