



Nominal Scales in Quantum Computing and Educational Assessment: A Comparative Review of Classification Systems and Standardization Challenges

Christian Ngozi, Odo Emmanuel Sunday & Adeyemi Olabanji Ayodeji

Department of Science Education, University of Nigeria, Nsukka

Corresponding Author ngozi.christianpg00252@unn.edu.ng

Abstract

This study presents a comparative review of the classification systems and standardization challenges associated with nominal scales in quantum computing and educational assessment. Nominal scales, which categorize data without implying quantitative value or order, are essential in labeling qubit states, algorithms, student characteristics, and test formats. Despite their widespread use, the interpretation and interoperability of nominal data across complex systems remain problematic. The study adopted a qualitative review design, drawing on secondary data sources including peer-reviewed journal articles, textbooks, technical documentation, and institutional reports published between 2015 and 2024. The data were collected using systematic literature review techniques, guided by clearly defined inclusion criteria. Content analysis was employed to identify patterns and challenges related to nominal data use and classification in both domains. Anchored in Symbolic Interactionism, the study reveals that the meanings assigned to nominal labels are socially constructed and context-dependent, which often results in inconsistent interpretations and miscommunication. In quantum computing, the lack of standardized symbolic representations complicates data sharing and reproducibility. In educational testing, disparities in nominal data usage can distort student evaluations and assessment outcomes. The study concludes that while nominal scales are foundational to classification, their current application lacks the precision required for interdisciplinary and computational demands. Recommendations include the development of unified labeling protocols and further empirical studies using mixed methods to explore user interpretation of nominal categories in both fields.

Keywords: Nominal scales, symbolic interactionism, quantum computing, educational assessment, standardization, qualitative review, data classification.

Introduction

In both quantum computing and educational assessment, the role of data in facilitating decision-making, analysis, and system performance cannot be overstated. At the heart of this data-centric process lies the need for effective classification and measurement, which serves as the foundation for organizing, interpreting, and acting upon information. One of the most basic yet widely applicable forms of measurement in both fields is the nominal scale. Unlike other scales that suggest order or magnitude—such as ordinal, interval, or ratio scales—the nominal scale functions by merely assigning labels or categories to distinguish between different entities or phenomena (DeVellis, 2017). Nominal scales are particularly essential in contexts where qualitative differentiation is more meaningful than numerical quantification. For example, in educational assessment, nominal scales are routinely

used to classify student gender, subject choices, school types, or test item categories. These categories are not ranked or ordered but serve purely as identifiers that allow for groupings and comparisons (Nitko & Brookhart, 2014). Similarly, in quantum computing, nominal classifications are employed in qubit identification, quantum state labeling, gate types, and algorithmic pathways. Each label serves to uniquely identify components of a quantum system, without implying that one qubit state is “greater” or “lesser” than another in any numerical sense (Nielsen & Chuang, 2010).

Quantum computing is a rapidly evolving field that leverages the principles of quantum mechanics—such as superposition, entanglement, and quantum interference—to perform computations that are infeasible for classical computers (Preskill, 2018; Arute

et al., 2019). It is characterized by features like qubits, parallelism, probabilistic output, and exponential scalability (Nielsen & Chuang, 2017; Biamonte et al., 2017). Quantum computing is important for solving complex problems in cryptography, optimization, and large-scale simulations due to its ability to process vast amounts of data simultaneously (Montanaro, 2016; Gyongyosi & Imre, 2019). In the context of educational data analysis, quantum models offer new ways to handle large datasets, apply machine learning algorithms, and improve decision-making systems through advanced data classification and pattern recognition (Schuld & Petruccione, 2018; Cerezo et al., 2021). For instance, using quantum-inspired algorithms, educational assessments can analyze vast learner data efficiently, enhancing adaptive testing and personalized learning paths while improving the accuracy of student profiling. However, the use of nominal scales in quantum computing presents an interesting challenge because, although quantum states can be labeled with discrete identifiers (e.g., $|0\rangle$ and $|1\rangle$), the underlying phenomena are governed by probabilistic and entangled systems, which do not conform neatly to traditional data representation methods (Preskill, 2018). As such, even though nominal labels are used to mark different qubit states or process components, these labels often fail to fully capture the dynamic and complex nature of the system, which complicates communication and interoperability, especially when integrating quantum computing with classical computing environments. Data scaling in this regard, will require some level of standardization.

The use of standards in data measurement and evaluation cannot be overemphasized. Standardization in data analysis refers to the process of establishing uniform formats, definitions, and procedures to ensure consistency, comparability, and reliability of data across different systems, studies, or contexts (Chen et al., 2018; Ghasemaghaei & Calic, 2020). Key features of standardization include uniform data labeling, structured variable definitions, interoperability, reproducibility, and clarity in data interpretation (Kitchin, 2014; Abella & Ortiz-de-Urbina-Criado, 2020). Its importance lies in reducing ambiguity, minimizing errors, enhancing data quality, and facilitating collaborative research, especially in multidisciplinary and cross-institutional settings (Vayena et al., 2018; Wilkinson et al., 2016). Standardization is widely applied in sectors such as healthcare, education, quantum science, and AI development where consistent classification and

communication of data are crucial (Leonelli, 2016; Taylor et al., 2019). In educational assessment, for example, standardized scales and labels improve the reliability of tests, enable valid comparisons across schools or regions, and support evidence-based decisions in curriculum planning and policy formulation.

On the issues of standardization in nominal scales, It was noted that nominal scales are often embedded within larger classification systems, and prevalent inconsistencies on how labels are applied or understood across different domains or platforms can lead to semantic and functional ambiguity. For example, two educational software platforms may use different nominal codes for the same category of student behavior, complicating data sharing or integration. In quantum computing, different research labs may use varied naming conventions for qubit arrangements or circuit configurations, which may not easily translate across platforms or tools (Arute et al., 2019).

Ultimately, while nominal scales serve a fundamental role in both quantum computing and educational measurement, their simplicity belies a number of complex challenges related to standardization which affects interoperability, and cross-domain communication. In quantum computing, nominal labels are frequently used to distinguish between qubit states, quantum gates, and measurement outcomes. However, these labels often lack universally accepted conventions. For example, different research teams may represent the same quantum operations using different symbolic or categorical nomenclature, leading to semantic inconsistencies that hinder collaboration and data integration (Preskill, 2018; Nielsen & Chuang, 2010). Moreover, the probabilistic and superpositional nature of quantum states makes it difficult to fully encapsulate their characteristics using simple nominal labels, which are inherently static and reductionist (Biamonte & Wittek, 2017). This mismatch between the complexity of the phenomena and the simplicity of the measurement scale can result in misleading or oversimplified interpretations. Likewise, educational institutions often adopt different coding schemes or categorizations for similar variables such as gender, school type, or course level without a shared standard. This leads to data interoperability issues during large-scale educational research, policy analysis, or cross-institutional comparisons (DeVellis, 2017). Without a consistent framework, data interpretation becomes

prone to errors, especially when combining or comparing datasets from multiple sources.

In summary, the core issue lies in the oversimplification of complex systems using nominal scales that were designed for more straightforward classification tasks. While useful in theory, nominal scales can become problematic in practice when applied across disciplines that demand precision, interoperability, and nuanced understanding. The absence of standardized frameworks for nominal classification contributes to miscommunication, misinterpretation, and ultimately undermines the reliability and utility of data-driven decisions in both quantum computing and educational measurement.

This paper focuses on a comparative review of how nominal scales are used in both quantum computing and educational testing, with special attention to how classification systems are structured and the challenges involved in standardizing them across disciplines. The growing integration of digital technologies in both fields raises important questions about compatibility, clarity, and scalability of these measurement practices.

Research Questions

- i. How consistent are classification systems within and across the two fields?
- ii. What are the inconsistencies in labeling and classification that hinder interoperability or standard analysis.
- iii. What are the major challenges of standardizing nominal scale data across quantum computing and educational assessment systems?

Theoretical Framework

Theory adopted for the study is the Symbolic Interactionism. The proponent of the theory was George Herbert Mead (1934), it was further developed by Herbert Blumer (1969). Symbolic Interactionism is a sociological theory that focuses on the use of symbols and language as core elements of all human interaction. It posits that meanings are not inherent but are constructed and interpreted through social interactions. The theory emphasizes that people act based on the meanings things have for them, and these meanings are derived from social interaction and modified through interpretation. In simpler terms, people do not respond to objects or concepts directly; instead, they respond to the meanings they attach to them—meanings that are developed socially.

Tenets of the Theory

- i. Meaning is socially constructed: The meaning of symbols and labels is formed through human interaction, not inherently fixed.
- ii. People act based on assigned meanings: Human actions are guided by what things mean to them.
- iii. Symbols are central to communication: Language and labeling are tools for interpreting and negotiating meaning.
- iv. Meaning is dynamic: Interpretations evolve based on new interactions and contexts.
- v. Context shapes understanding: The same symbol can have different meanings depending on the environment or discipline.

Symbolic Interactionism is highly relevant to this study because nominal scales are essentially systems of symbols and labels. Whether in quantum computing (e.g., qubit state labels, gate identifiers) or educational assessment (e.g., gender, test formats, subject codes), these labels are interpreted based on context and human interaction.

In quantum computing, the classification of states and gates is symbolic and varies between research groups or quantum programming platforms. What one system refers to as “|0>” or “X-gate” may carry different implications or structures elsewhere—showcasing contextual and constructed meaning. Alternatively, in educational testing, nominal data like student categories, answer choices (A, B, C...), or school types also gain meaning through institutional or cultural frameworks. Misinterpretation occurs when different systems or individuals assign different meanings to the same label. This theory helps explain why inconsistencies in labeling systems arise, and why standardization is so difficult—because the labels’ meanings are not fixed but interpreted differently by various actors.

Methodology

This study employed an explorative research design using a qualitative approach, relying on secondary data to examine how nominal scales function and pose challenges in both quantum computing and educational assessment. Method of data collection was the use of documentary analysis. Data were sourced from peer-reviewed journals, books, and academic databases such as Google Scholar, IEEE Xplore, ERIC, and JSTOR, focusing on literature from 2009 to 2024. The data were analyzed using Content analysis, guided by Braun and Clarke’s (2006) framework, which involved identifying and interpreting patterns related to

classification, labeling, and standardization across both fields. Key themes that emerged include the structural role of nominal scales, application in labeling systems, standardizations, inconsistencies in interpretation, and the implications for interoperability in interdisciplinary contexts.

Results

Major findings of the study includes:

- i. In response to research question one, findings show that nominal scales in both quantum computing and educational assessment consistently serve to categorize data without implying order; however, while educational categories are typically mutually exclusive, quantum categories can overlap due to phenomena like superposition, making cross-field alignment more complex.
- ii. In response to research question two, findings show that both fields face inconsistencies in labeling such as varied terms for similar categories that hinder interoperability and standard analysis, with existing frameworks like ISCED in education and emerging quantum taxonomies often applied unevenly, reducing comparability and data fidelity.
- iii. In response to research question three, findings show that a major challenge in standardizing nominal scale data lies in the absence of universally enforced classification protocols; lessons from quantum computing's progress in standardizing terminology and adopting flexible, adaptive classification models could guide education toward clearer, globally aligned, and more dynamic nominal categories.

Discussion

Conceptual Similarities and Differences

Nominal scales are fundamental tools for categorizing information without implying order, magnitude, or rank. In educational testing, they are widely used to label demographic data, student responses, and institutional characteristics. For instance, multiple-choice answers are often labeled “A,” “B,” “C,” or “D” without implying that one choice is quantitatively higher than another (McMillan, 2016). These categories are mutually exclusive and support administrative clarity, yet they offer limited analytical depth since they cannot support statistical operations such as averaging or correlating variables (Nitko & Brookhart, 2014). As a result, knowing that a student

selected “Option B” reveals only the chosen label, not the depth of their understanding—restricting educators’ ability to draw meaningful inferences (Kubiszyn & Borich, 2016).

In quantum computing, nominal classification is equally central, applied to identify particles, qubit states, and quantum operations. Qubits are typically labeled as $|0\rangle$, $|1\rangle$, or more complex states like $|\psi\rangle$, with such symbols serving a purely differentiating role rather than indicating magnitude (Nielsen & Chuang, 2010). Quantum gates such as the Hadamard, Pauli-X, or Toffoli are also nominally labeled, and their function is determined by the operation they perform, not by the label itself (Preskill, 2018). A key difference is that, due to superposition and entanglement, a single quantum entity may require multiple overlapping identifiers, unlike the strictly mutually exclusive categories typical in educational systems (Arute et al., 2019), implying that a choice such as gender, answer choice or class level can only be in one category at a time (e.g in schools students pick one box and tick it, they cannot be in to boxes at once).

Inconsistencies Hindering Interoperability

A major shared challenge between the two fields lies in the inconsistency of category definitions and naming conventions. In education, terms like “Satisfactory” and “Proficient” may denote similar performance levels in different systems but lack a shared framework, creating ambiguity in cross-institutional or cross-national comparisons (Gronlund & Waugh, 2009). Similarly, in quantum computing, different research labs may use alternative symbols or shorthand for equivalent quantum states or operations, making collaborative work and data integration more difficult (Zhou, 2020; QED-C, 2020). While both domains have attempted to address these inconsistencies—through the International Standard Classification of Education (ISCED) in education and emerging taxonomies in quantum computing—these frameworks are not consistently enforced. The result is reduced data fidelity, as labels are often context-dependent and vary in meaning across systems. This lack of coherence is particularly problematic in comparative studies, policy reporting, or inter-lab research, where uniformity is essential for interoperability and accurate interpretation.

Challenges in Standardization

Standardizing nominal scales is inherently difficult because they are non-hierarchical and context-specific. Naming a quantum state as $|A\rangle$ or $|B\rangle$, or labeling student work as “Correct,” “Incorrect,” or “Incomplete,” conveys no inherent order or magnitude. Consequently, creating universal rules for these categories is challenging, especially when their meaning can shift depending on the context in which they are applied (Nitko & Brookhart, 2014; Kubiszyn & Borich, 2016). For example, in education, what counts as a “Pass” or “Fail” may differ by region or curriculum, just as a quantum label might signify different particle interactions in separate studies.

In both quantum computing and educational assessment, the absence of universally enforced classification protocols undermines interoperability. Although organizations like the QED-C are working to unify quantum terminology, and ISCED offers a potential standard for educational classifications, uptake is inconsistent. This creates an urgent need for global frameworks that define and align nominal categories across contexts.

One promising avenue comes from quantum computing’s progress in flexible classification. The ability of quantum systems to represent overlapping categories via superposition suggests how educational assessments could handle complex responses that do not fit neatly into one category. For example, a student’s answer might simultaneously align with multiple rubric categories (e.g., creativity and critical thinking). Similarly, adaptive testing models could allow category labels to evolve based on a student’s performance over time, creating more individualized assessments. This quantum-inspired adaptability could make nominal classifications in education more dynamic and meaningful while maintaining global comparability (Nielsen & Chuang, 2010; Preskill, 2018). From these discussions, several shared challenges emerge such as:

- i. Inconsistent terminology and symbols across systems hinder comparability.
- ii. Non-hierarchical nature of nominal data complicates the development of universal standardization rules.
- iii. Context-dependent meanings lead to misinterpretation when data is shared across institutions or regions.
- iv. Uneven application of existing frameworks such as ISCED and quantum taxonomies reduces their intended impact.

- v. Rigid classification systems limit flexibility, underscoring the need for adaptive, context-aware models.

Conclusion

This review explored the challenges of using nominal scales in two complex fields: quantum computing and educational assessment. While nominal classification offers a basic framework for labeling and organization, its simplicity becomes a limitation in systems that demand consistency, precision, and interoperability. Drawing from Symbolic Interactionism, it becomes clear that the meanings attached to nominal labels are socially constructed, context-dependent, and often misunderstood when applied across diverse systems. This lack of standardization can hinder data interpretation, cause miscommunication, and compromise the quality of decision-making. Therefore, there is a pressing need for clearer frameworks and consistent labeling practices in both fields to ensure valid interpretations and reliable data usage.

Suggestions for Further Study

Based on the findings the following suggestions were made for further study:

- i. Standardized coding protocols for nominal data can improve interoperability in quantum data analysis.
- ii. Nominal scale challenges across additional fields such as medicine, artificial intelligence, or psychology.
- iii. Mixed-methods Survey on how educators and researchers interpret nominal data in large-scale assessments.
- iv. Integrating AI tools to interpret nominal data across educational and computational settings.

References

- Arute, F., Arya, K., Babbush, R., Bacon, D., Bardin, J. C., Barends, R., & Martinis, J. M. (2019). Quantum supremacy using a programmable superconducting processor. *Nature*, 57(4), 505–510. <https://doi.org/10.1038/s41586-019-1666-5>
- Biamonte, J., & Wittek, P. (2017). Quantum machine learning. *Nature*, 549(7671), 195–202. <https://doi.org/10.1038/nature23474>



- Cohen, L., Manion, L., & Morrison, K. (2018). *Research methods in education* (8th ed.). Routledge.
- DeVellis, R. F. (2017). *Scale development: Theory and applications* (4th ed.). Sage Publications.
- Gronlund, N. E., & Waugh, C. K. (2009). *Assessment of student achievement* (9th ed.). Pearson Education.
- Kubiszyn, T., & Borich, G. (2016). *Educational testing and measurement: Classroom application and practice* (11th ed.). Wiley.
- McMillan, J. H. (2016). *Classroom assessment: Principles and practice for effective standards-based instruction* (6th ed.). Pearson.
- Nielsen, M. A., & Chuang, I. L. (2010). *Quantum computation and quantum information* (10th Anniversary ed.). Cambridge University Press.
- Nitko, A. J., & Brookhart, S. M. (2014). *Educational assessment of students* (7th ed.). Pearson Education.
- Preskill, J. (2018). *Quantum computing in the NISQ era and beyond*. *Quantum*, 2, 79. <https://doi.org/10.22331/q-2018-08-06-79>
- Quantum Economic Development Consortium (QED-C). (2020). *Quantum terminology standardization report*. <https://quantumconsortium.org>
- Stevens, S. S. (1946). *On the theory of scales of measurement*. *Science*, 10(3), 677–680. <https://doi.org/10.1126/science.103.2684.677>
- UNESCO. (2012). *International Standard Classification of Education: ISCED 2011*. Montreal: UNESCO Institute for Statistics.
- Zhou, L. (2020). A survey on quantum programming languages and quantum software tools. *ACM Computing Surveys (CSUR)*, 53(6), 1–34. <https://doi.org/10.1145/3417980>